

A grayscale HiRISE image of the Martian surface, showing a rugged terrain with numerous craters, ridges, and valleys. The image is the background for the entire slide.

HiRISE image PSP\_010553\_1560

# Testable Hypotheses and Candidate Science Targets Within the Eberswalde Landing Ellipse

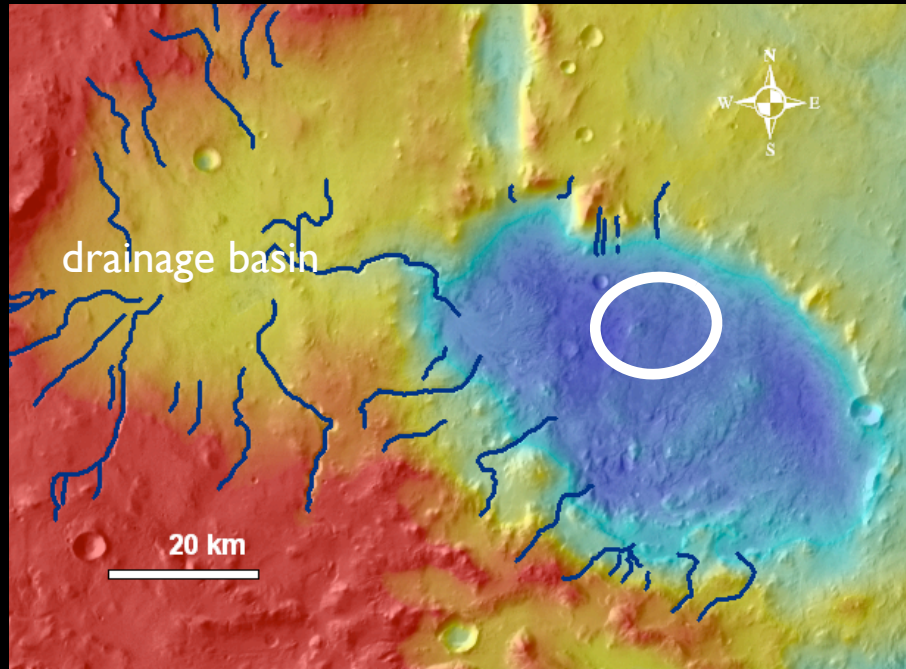
Melissa Rice, Jim Bell, Sanjeev Gupta, Nick Warner & LSWG colleagues

# Overview:

1. Regional context of landing ellipse
2. Units and features within the ellipse
3. Contacts and stratigraphic relationships
4. Relationships to mineralogic units
5. Initial proposed traverses for hypothesis testing

# MOLA Topography

Image Credit: MOLA team / NASA Goddard Spaceflight Center



-1600 m  
MOLA elevation  
0 m

Rice *et al.* (2010 in prep)

# THEMIS Thermal Inertia

Image Credit: Fergason et al. (2006) and the THEMIS Team



80  
Thermal Inertia  
 $\text{J m}^{-2} \text{K}^{-1} \text{s}^{-1/2}$   
525

context

units

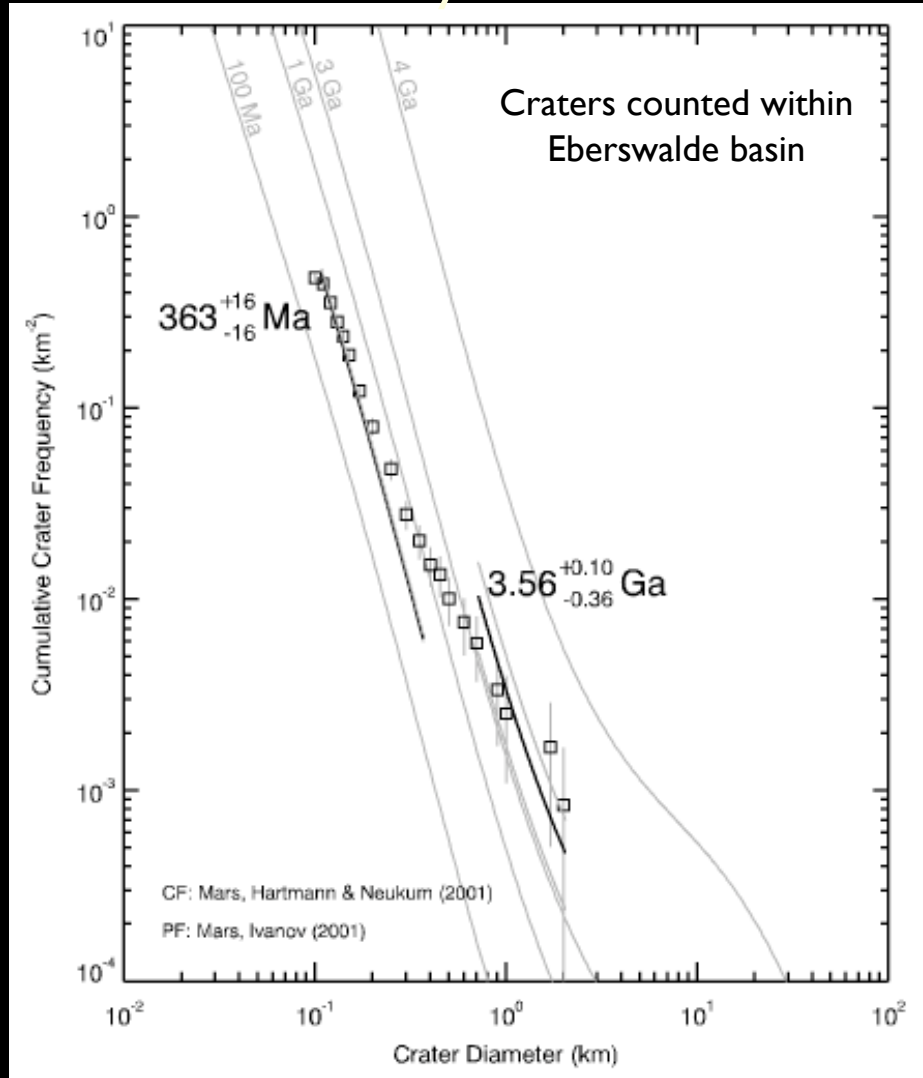
contacts

mineralogy

traverses

# Eberswalde Crater Resurfacing:

## *Crater statistics by Nick Warner*



- 571 craters ( $D > 100$  m) on the Eberswalde floor (area = 1188 km<sup>2</sup>)
- craters with  $D > 700$  m follow  $\sim 3.6$  Ga isochron
- craters with  $D < 200$  m follow  $\sim 360$  Ma isochron
- gradual decline in slope between  $D=200$  m and 700 m

### INTERPRETATIONS:

- steady state, long-term resurfacing between late Noachian and recent Amazonian
- very little geologic activity in the recent Amazonian
- much of the ancient surface is no longer there

context

units

contacts

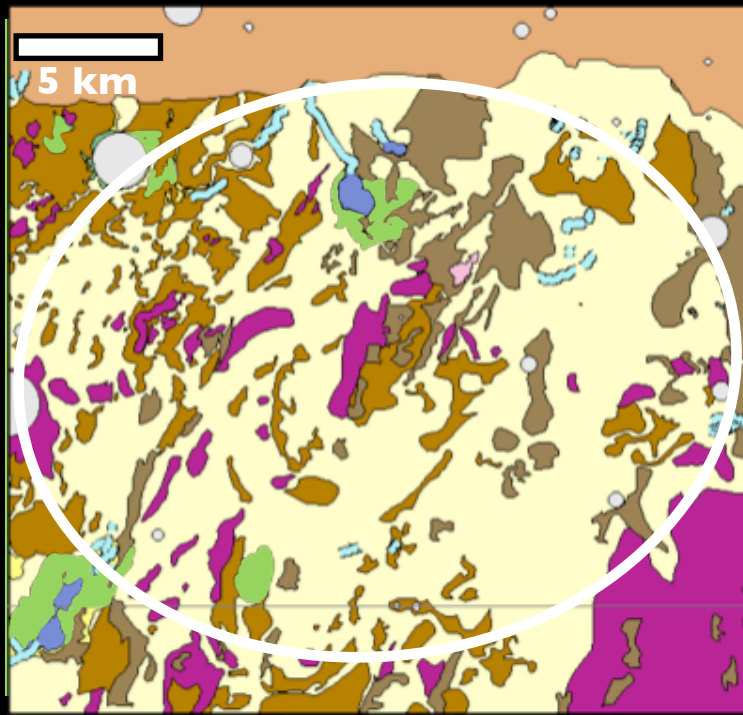
mineralogy

traverses



# Within the Landing Ellipse:

## Photostratigraphic Units:



Rice et al. (2010 in prep)

- Mass wasting deposits
- Aeolian bedforms
- Mantling unit

*THIS TALK:*

- Layered light-toned unit
- Fractured light-toned unit
- Discontinuous light-toned unit
- Brecciated ridge-forming unit

## Photomorphologic Features:

- Sinuuous ridges

context

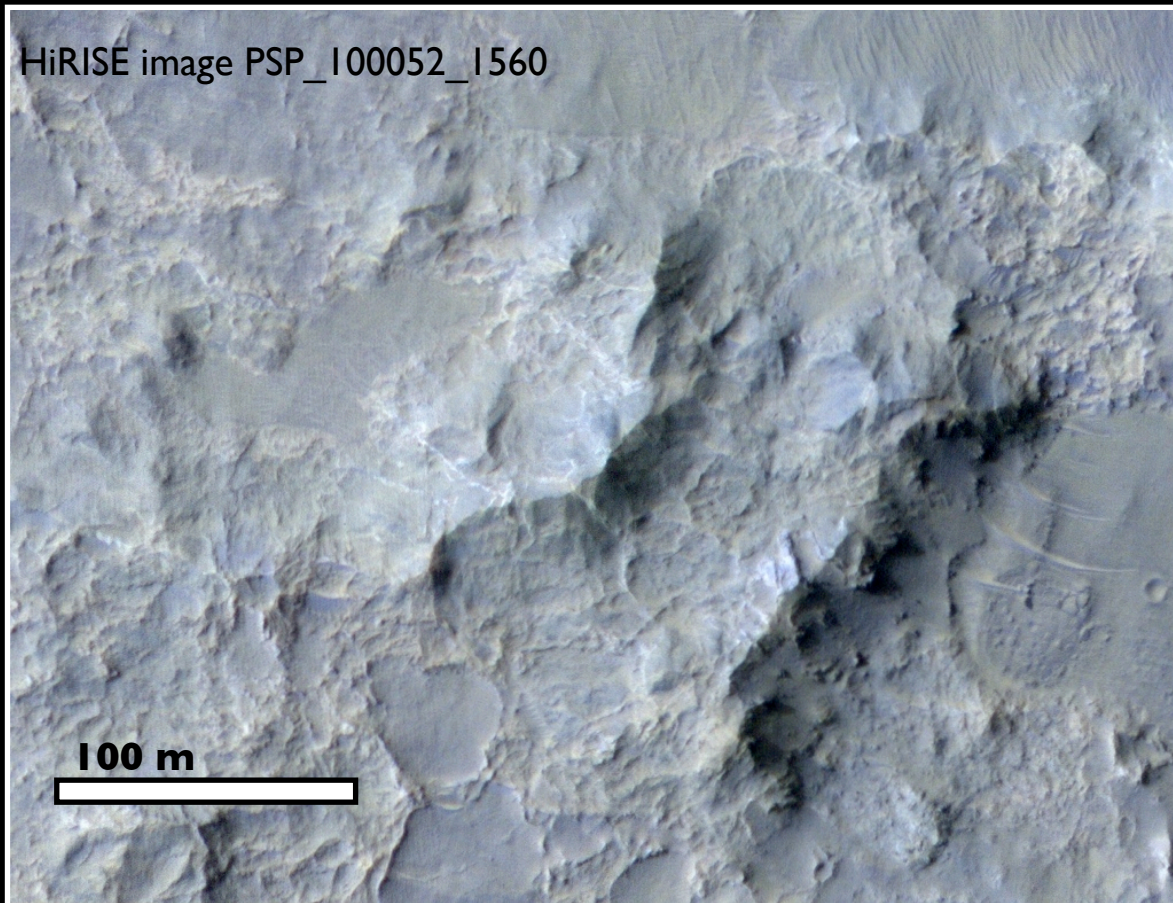
units

contacts

mineralogy

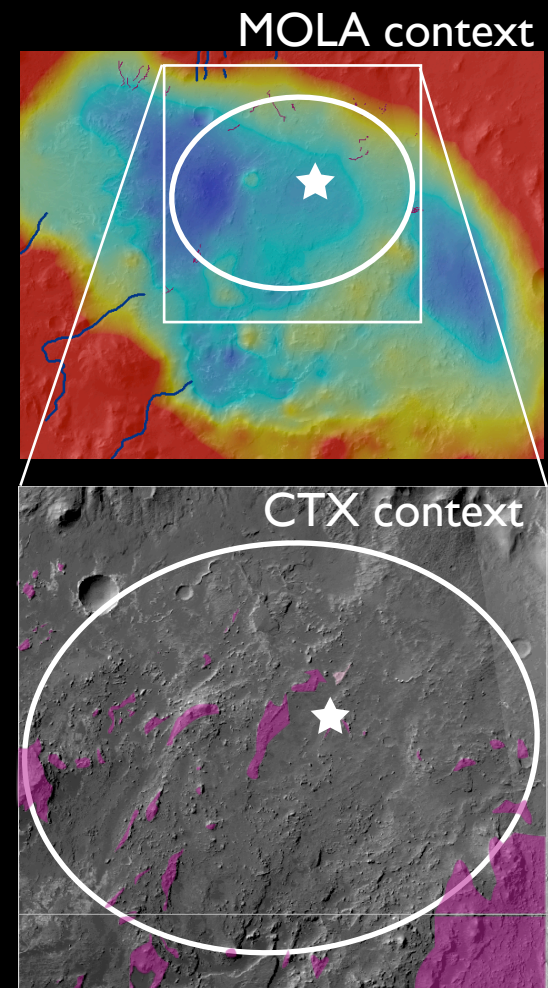
traverses

# 1. Brecciated Ridge-Forming Unit



## OBSERVATIONS:

ridge-forming unit with light-toned veins  
in some locations, ~10m blocks encased in  
finer, light-toned matrix



## INTERPRETATION:

may be megabreccia from the Holden  
impact event (Scheiber *et al.*, 2008) or  
fractured bedrock

context

units

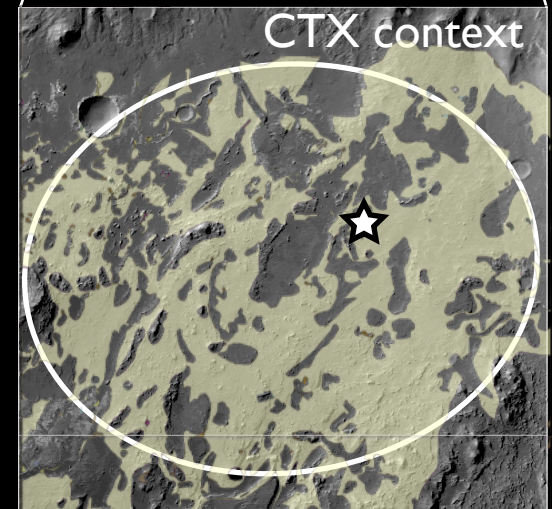
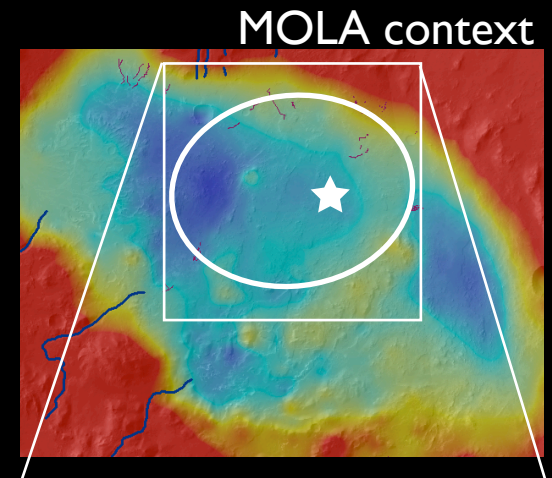
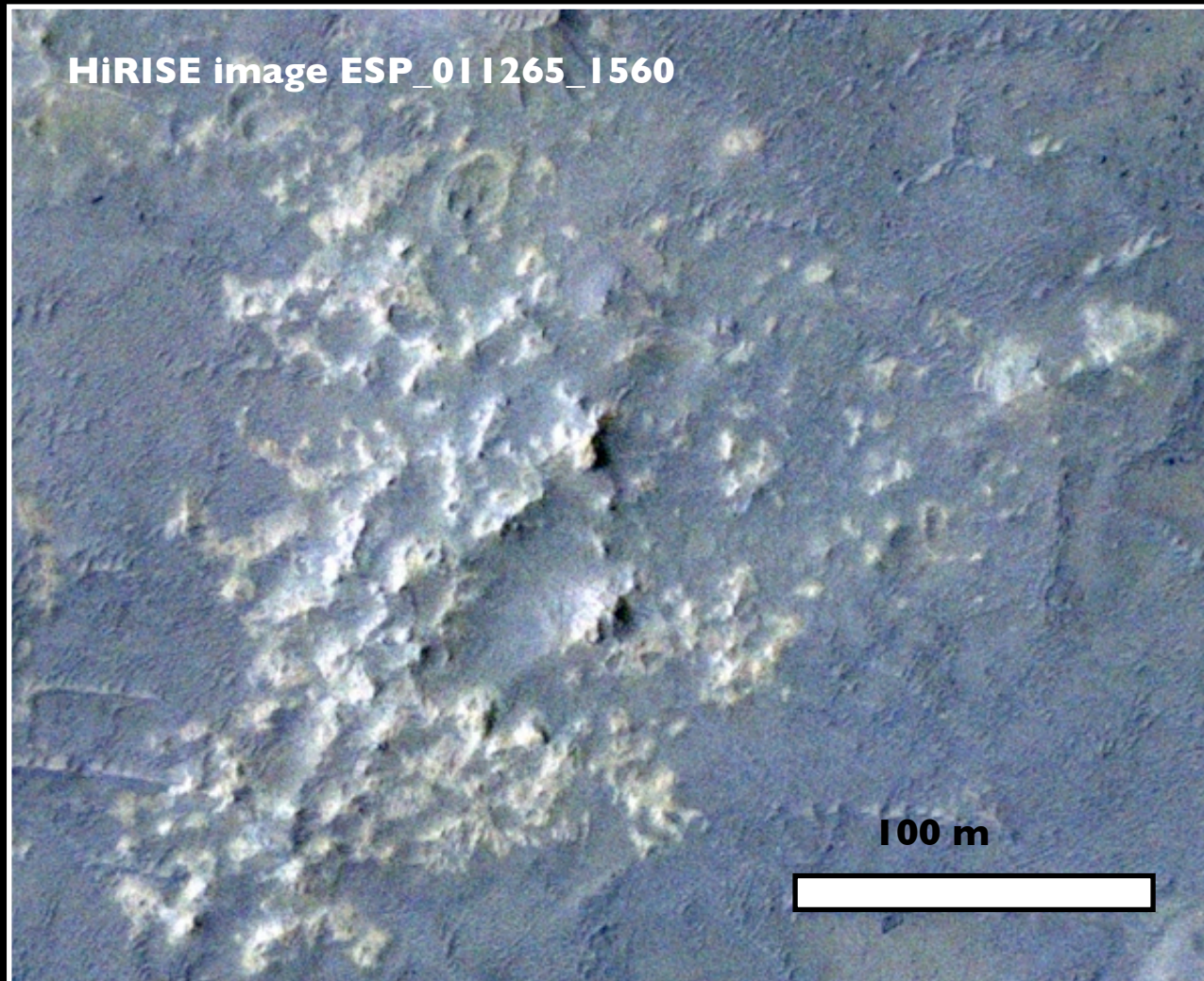
contacts

mineralogy

traverses



## 2. Discontinuous Light-Toned Unit



**OBSERVATIONS:**  
variably eroded, preserves  
meter-scale quasi-circular  
pits

context

units

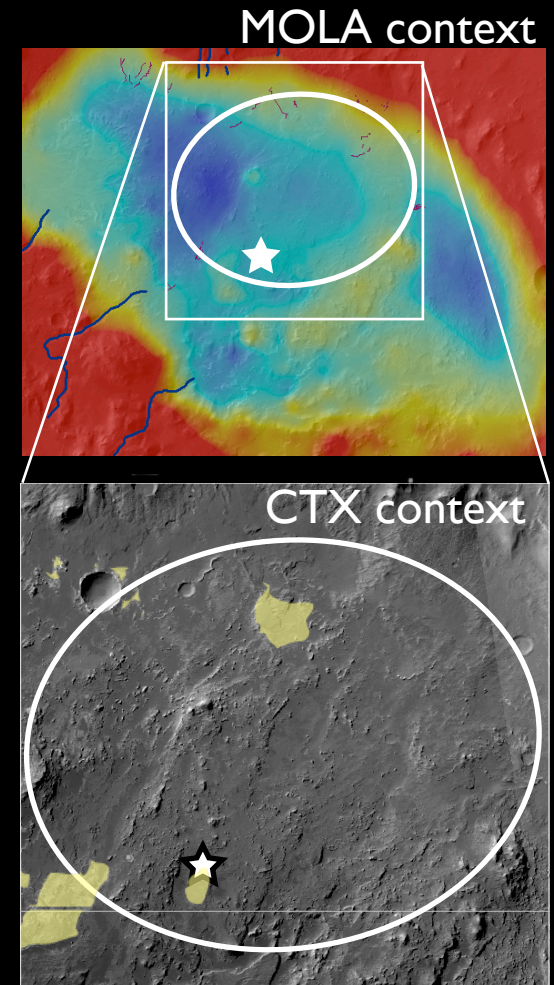
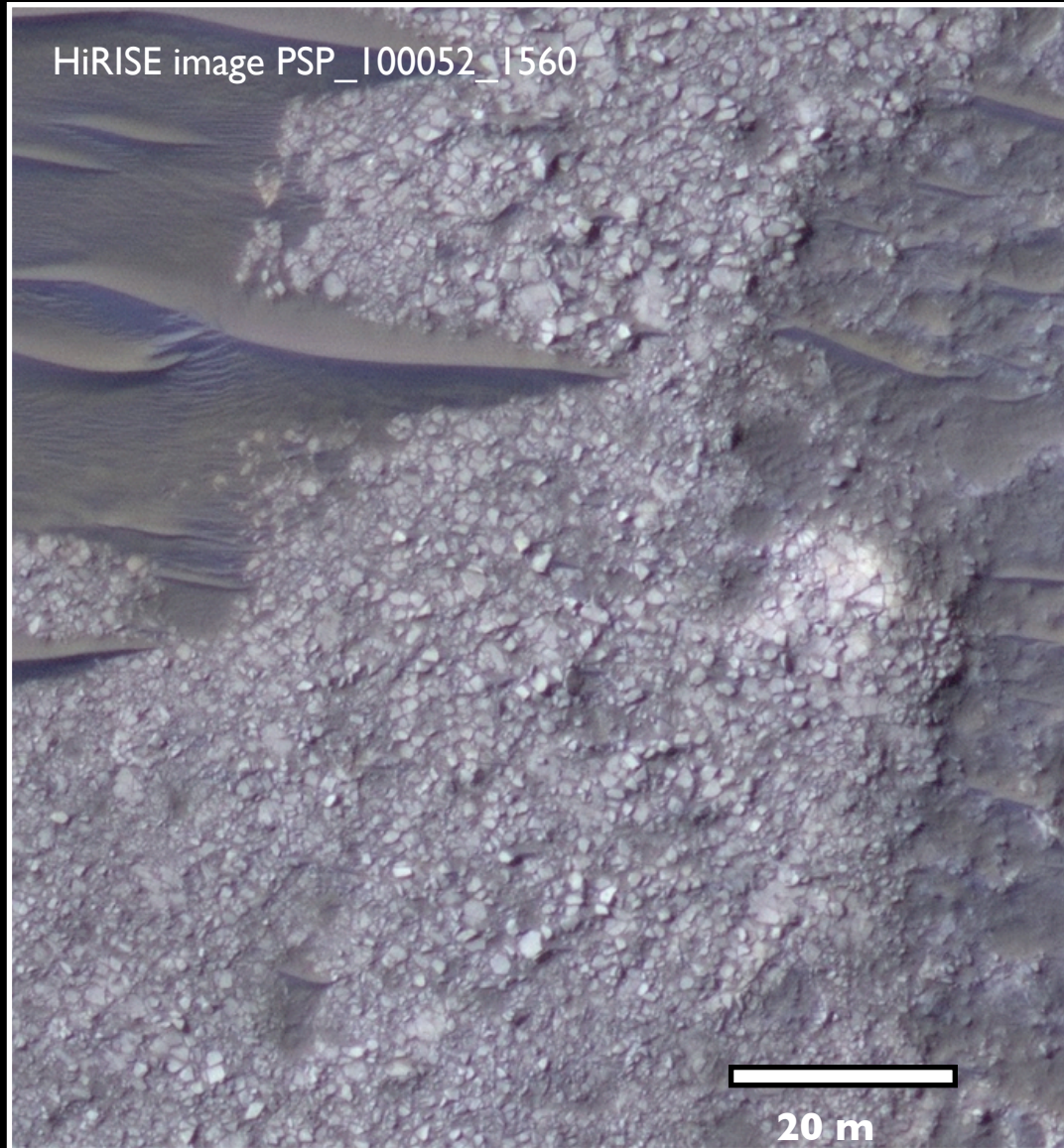
contacts

mineralogy

traverses



### 3. Fractured Light-Toned Unit



**OBSERVATION:**  
polygonal fractures in  
horizontal, light-toned material

context

units

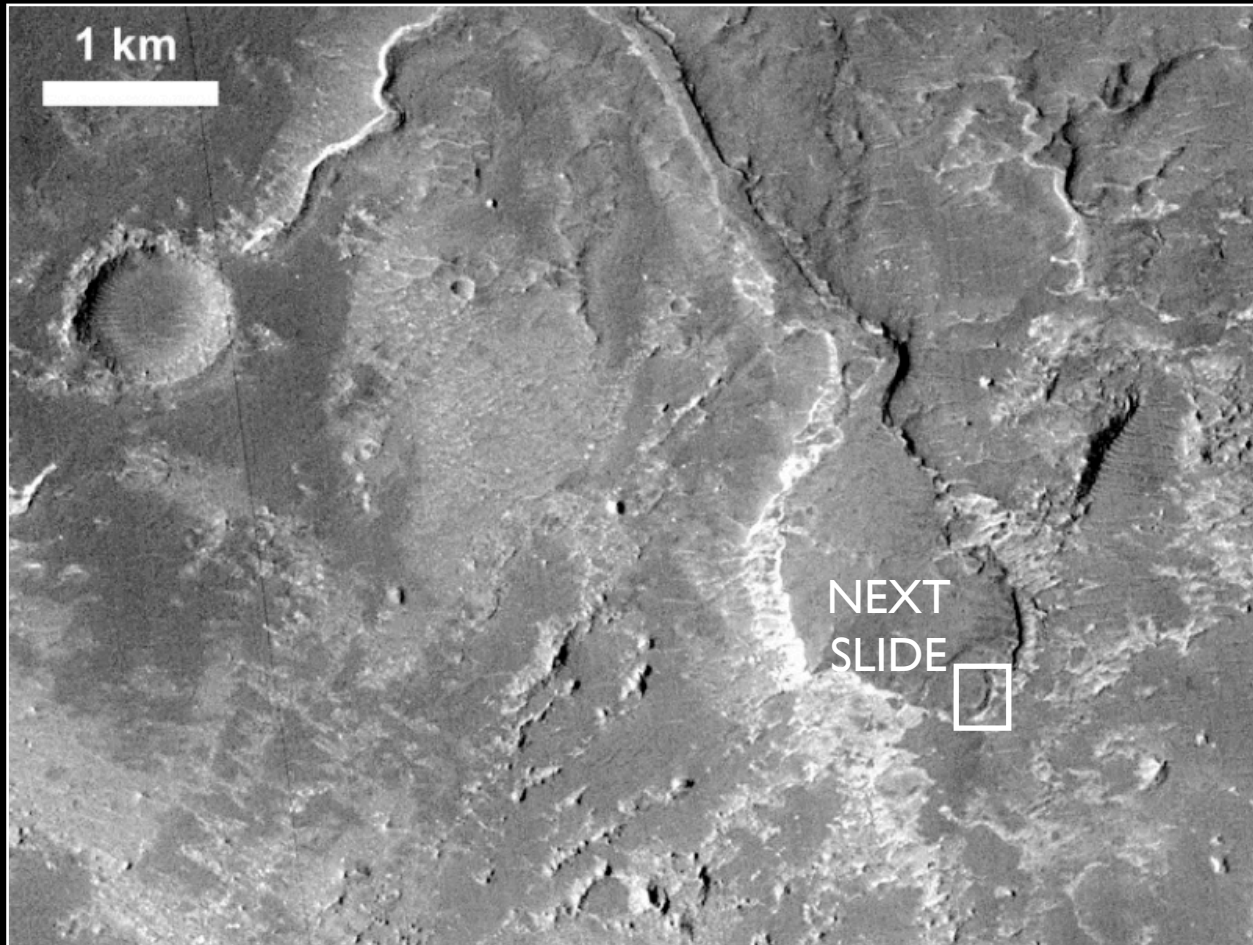
contacts

mineralogy

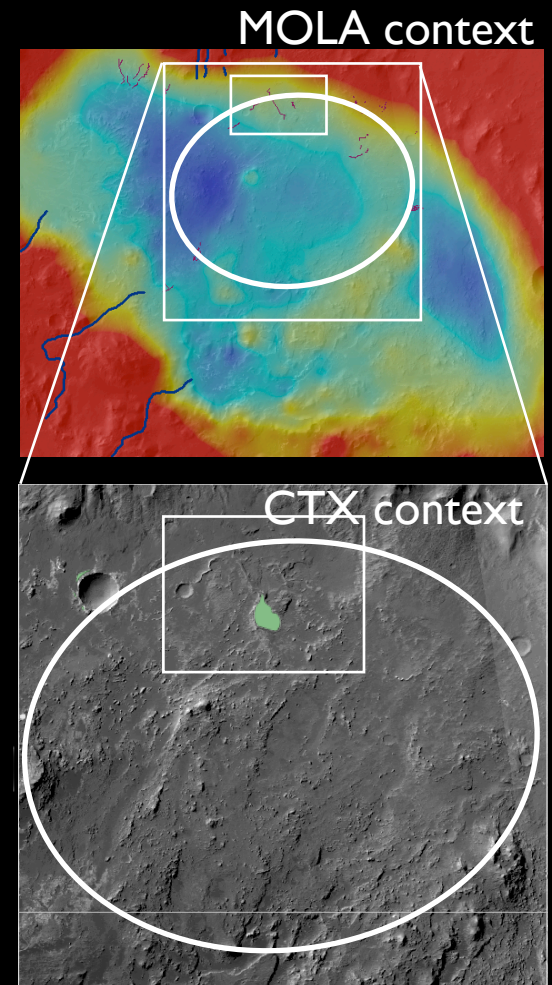
traverses



## 4. Layered Light-Toned Unit



CTX image P01\_001336\_I560



context

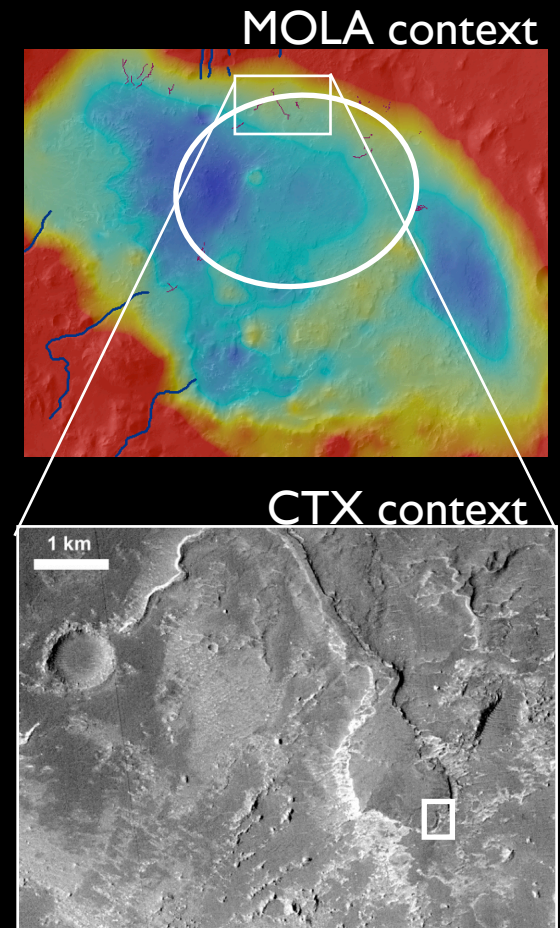
units

contacts

mineralogy

traverses

## 4. Layered Light-Toned Unit



**OBSERVATION:**  
layers of light-toned rock  
visible in terminus of lobate  
feature

context

units

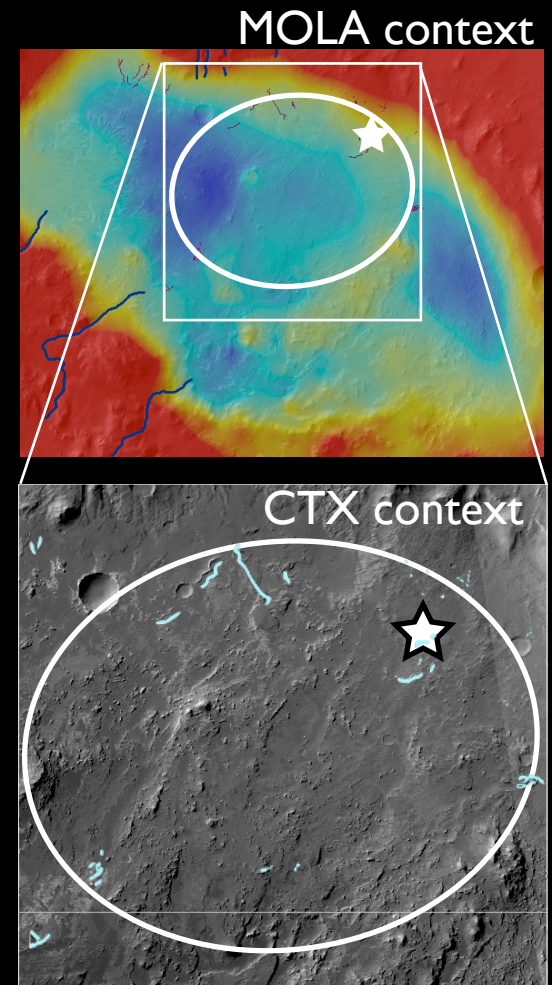
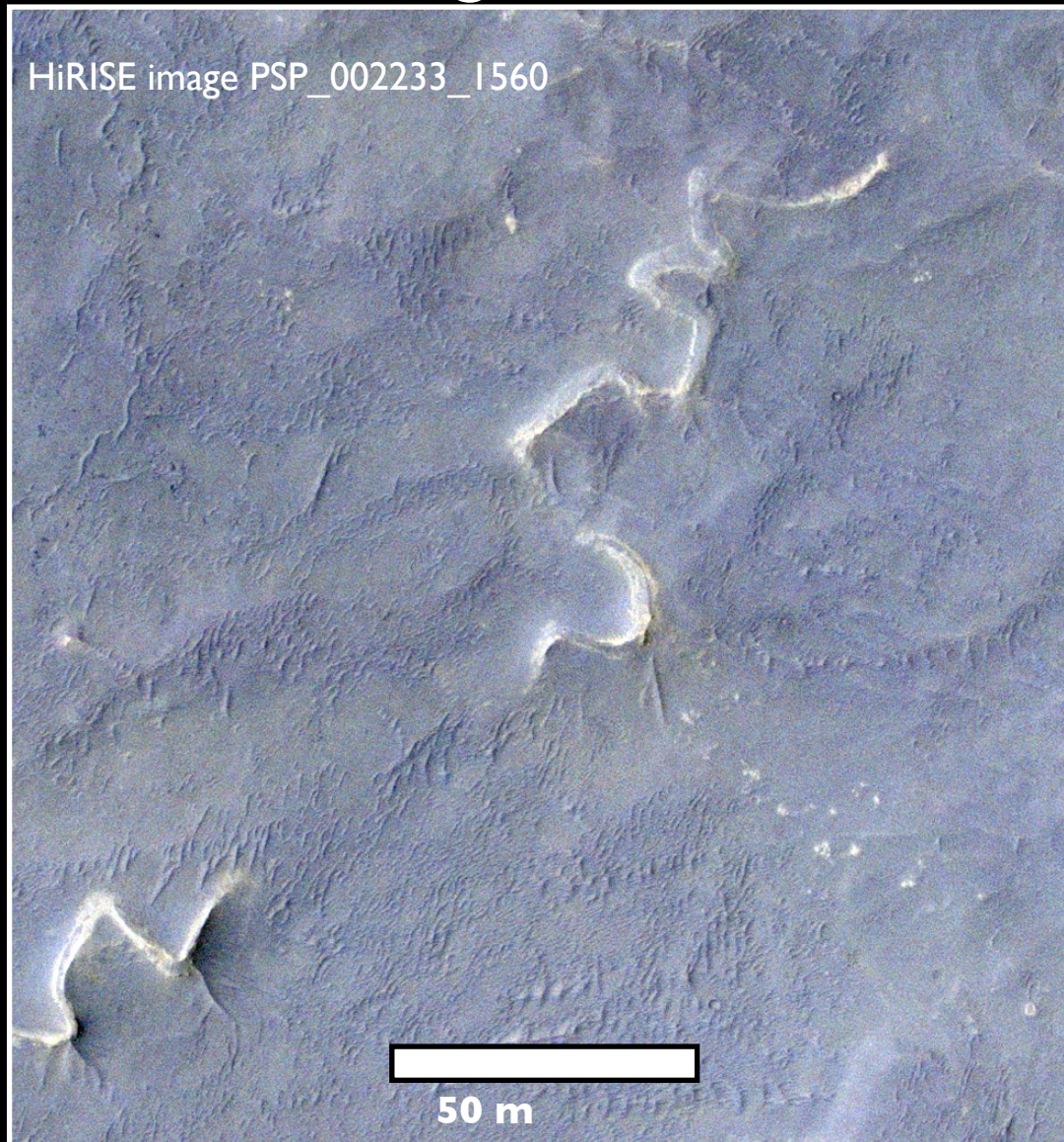
contacts

mineralogy

traverses



## 5. Sinuous Ridges



**OBSERVATION:**  
light-toned, ridge-forming  
material

context

units

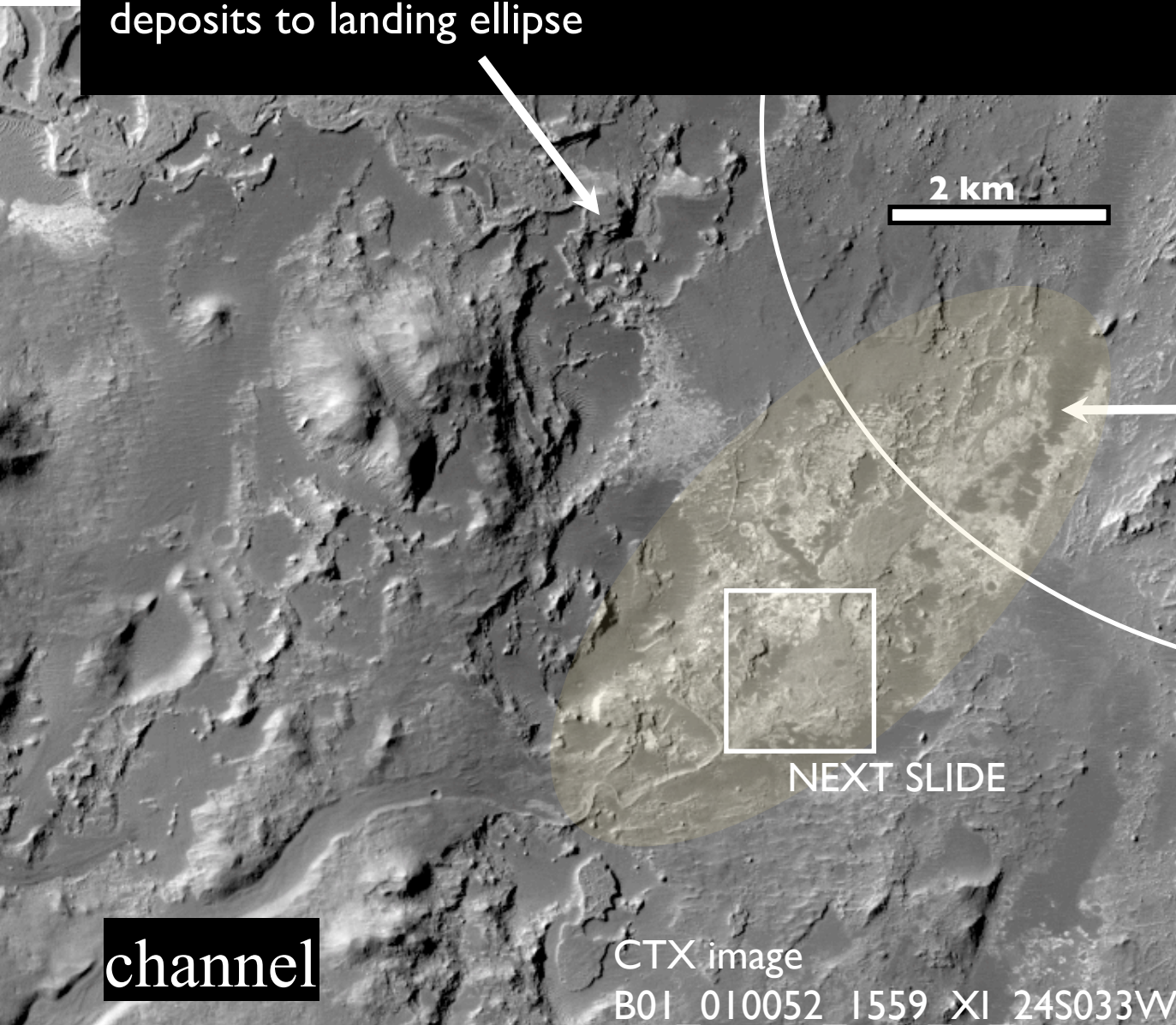
contacts

mineralogy

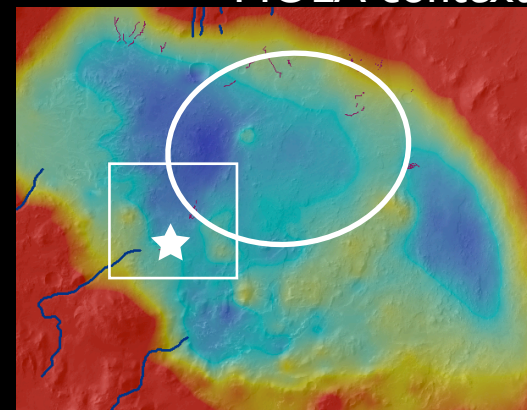
traverses



closest Eberswalde delta/fan  
deposits to landing ellipse



MOLA context



**Interpretation:**  
yellow region is extent of  
preserved sediments  
transported into Eberswalde  
via the channel to the SW

context

units

contacts

mineralogy

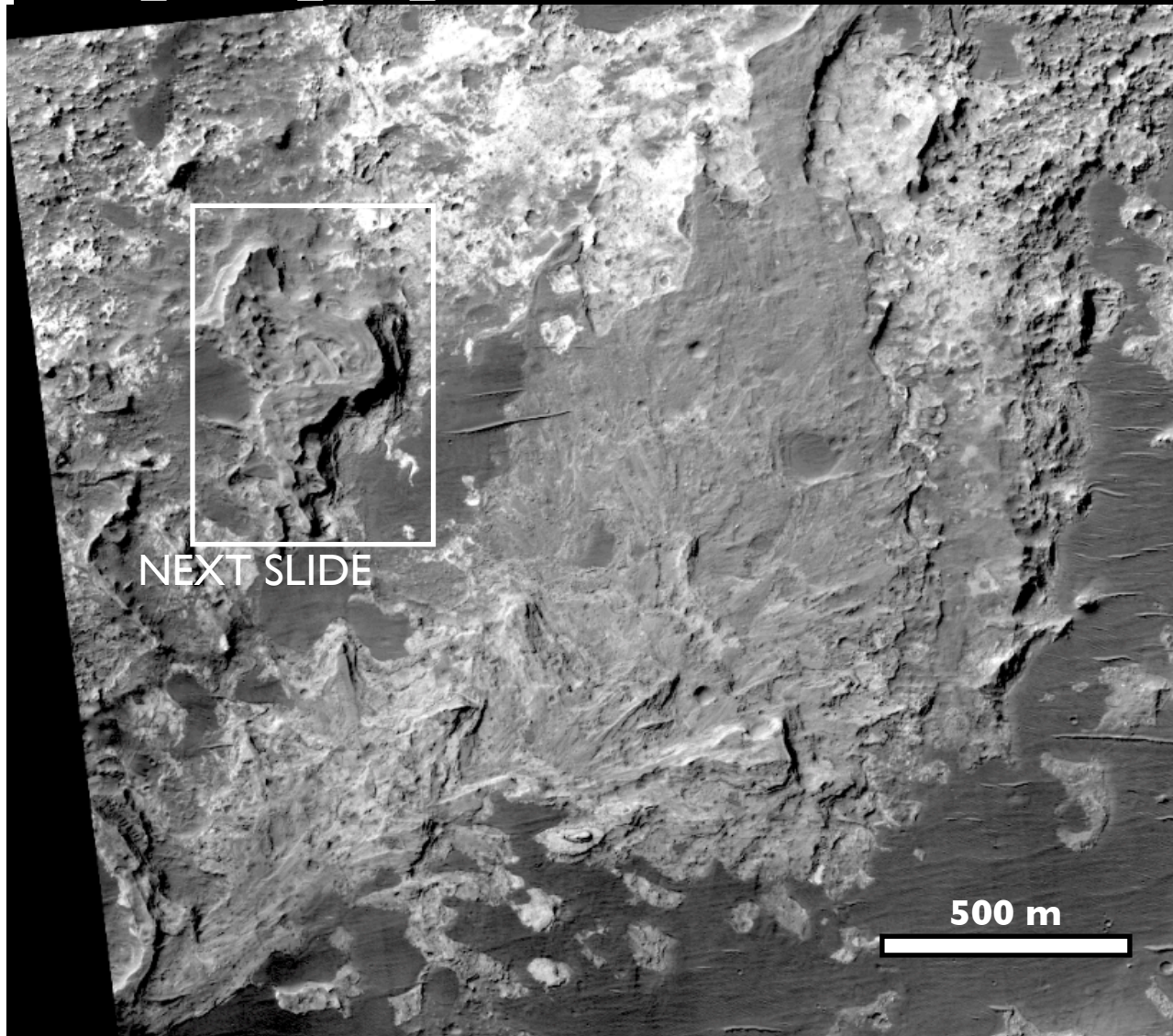
traverses



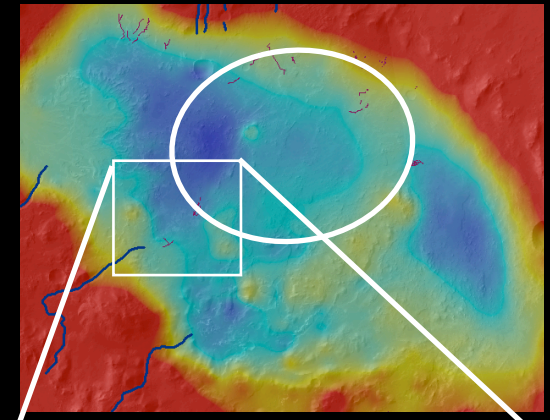
# 5. Sinuous Ridges

**NEW HiRISE image (9 June 2010)**

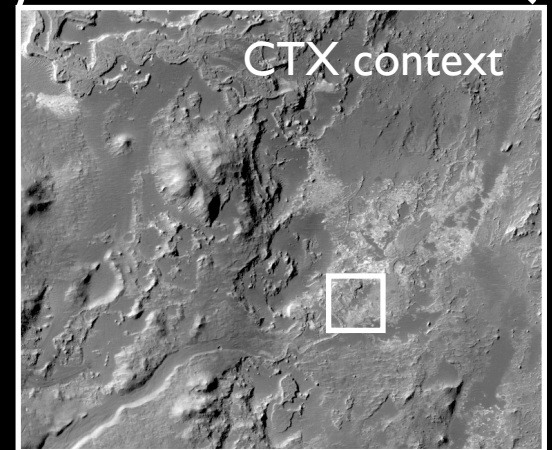
ESP\_018056\_1555\_RED



MOLA context



CTX context



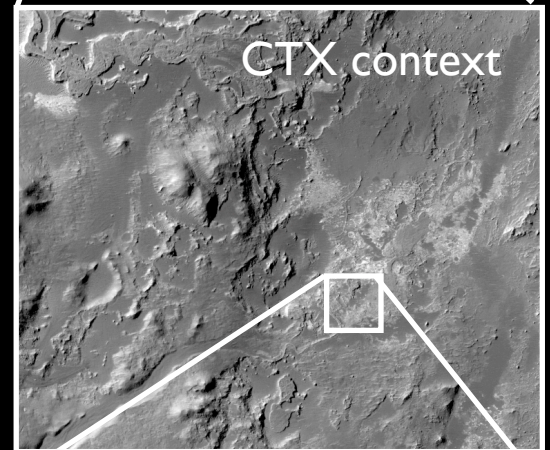
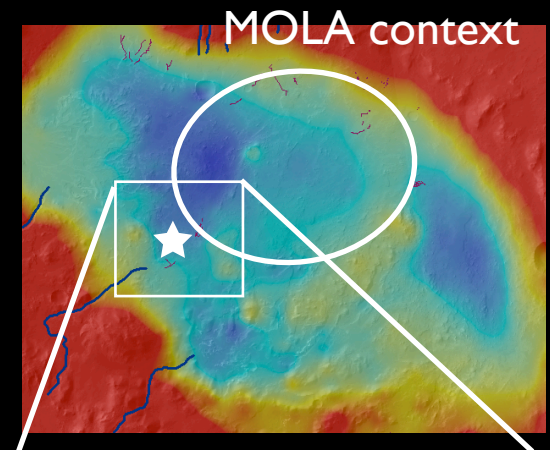
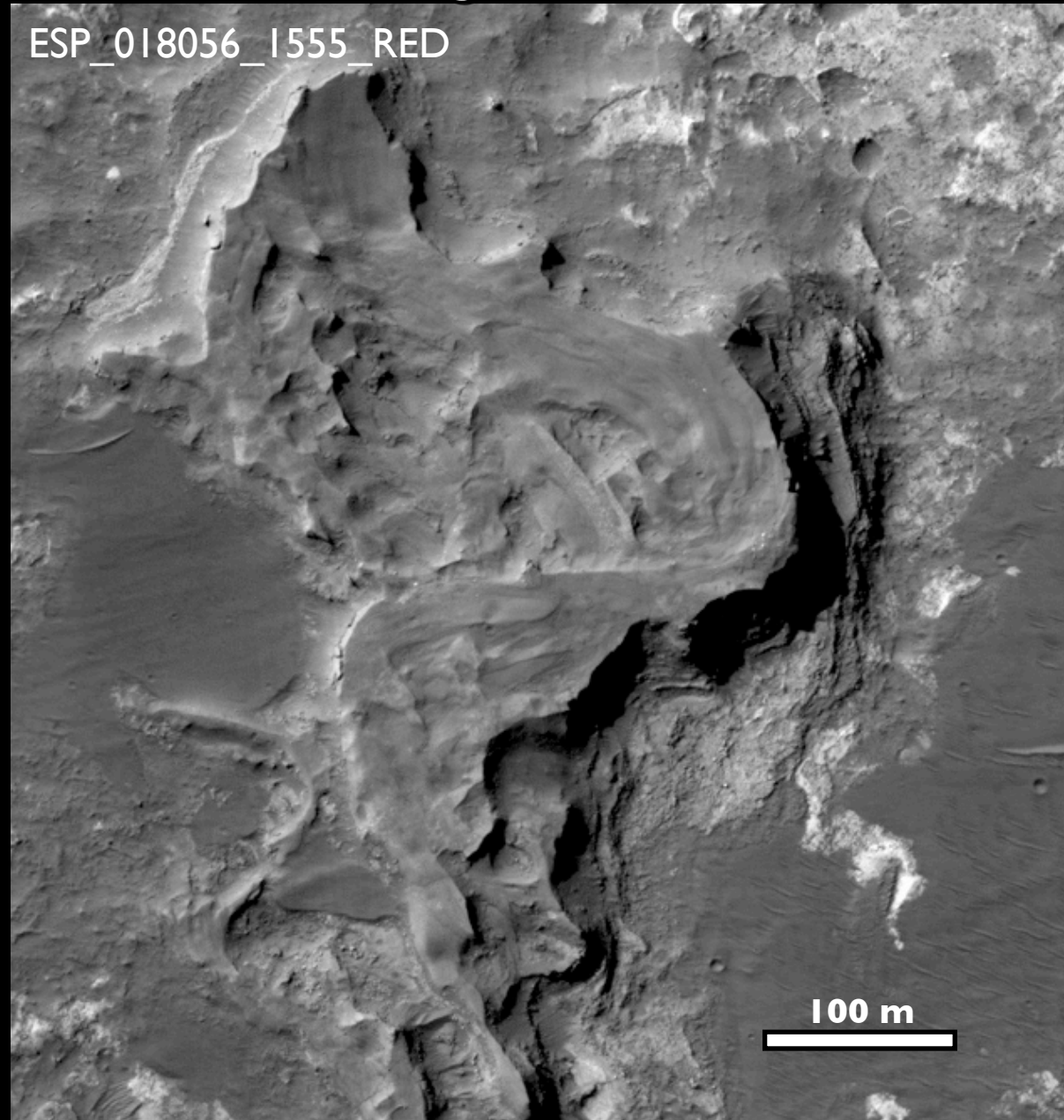
## **Observations:**

digitate terraces of light-toned, layered rock

preservation of highly sinuous forms

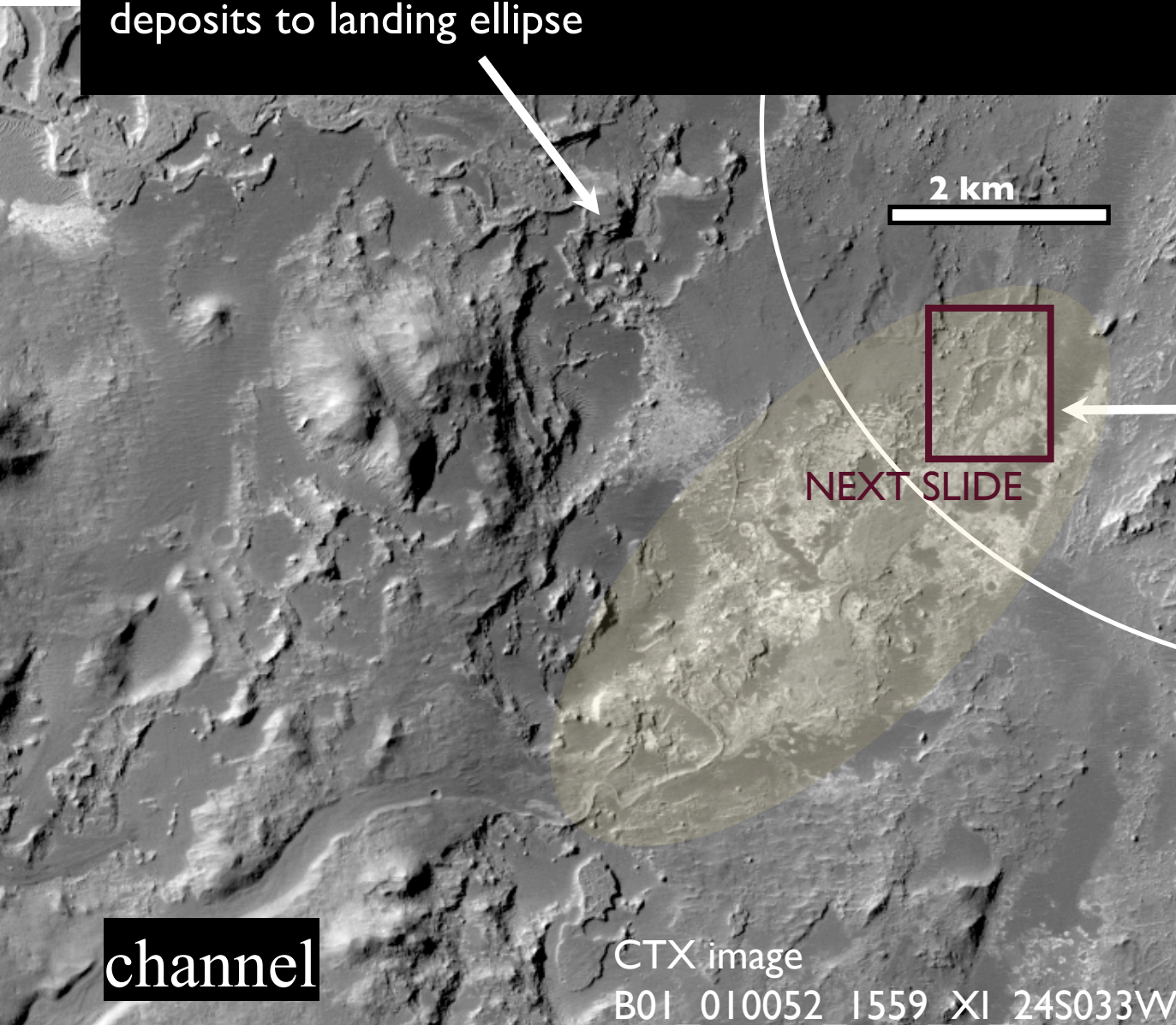


# 5. Sinuous Ridges

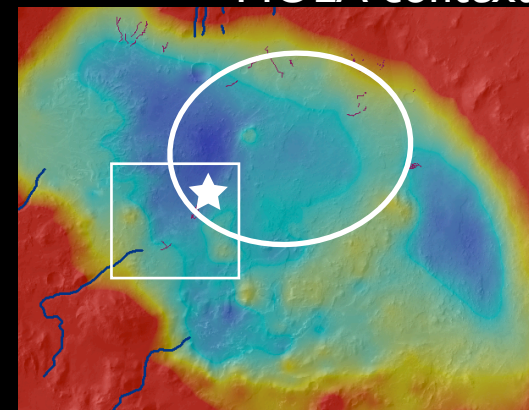




closest Eberswalde delta/fan deposits to landing ellipse



MOLA context



**Interpretation:**  
yellow region is extent of preserved sediments transported into Eberswalde via the channel to the SW

context

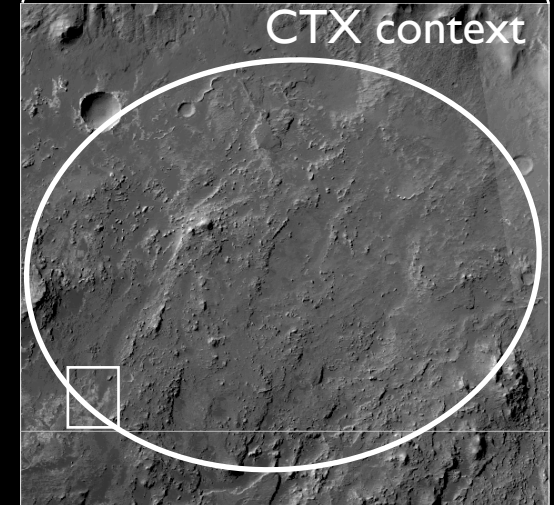
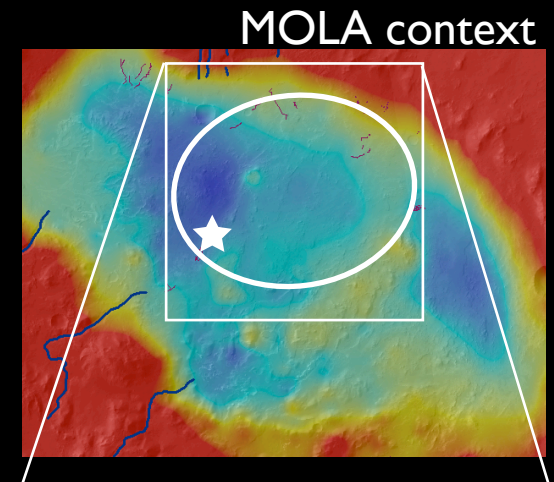
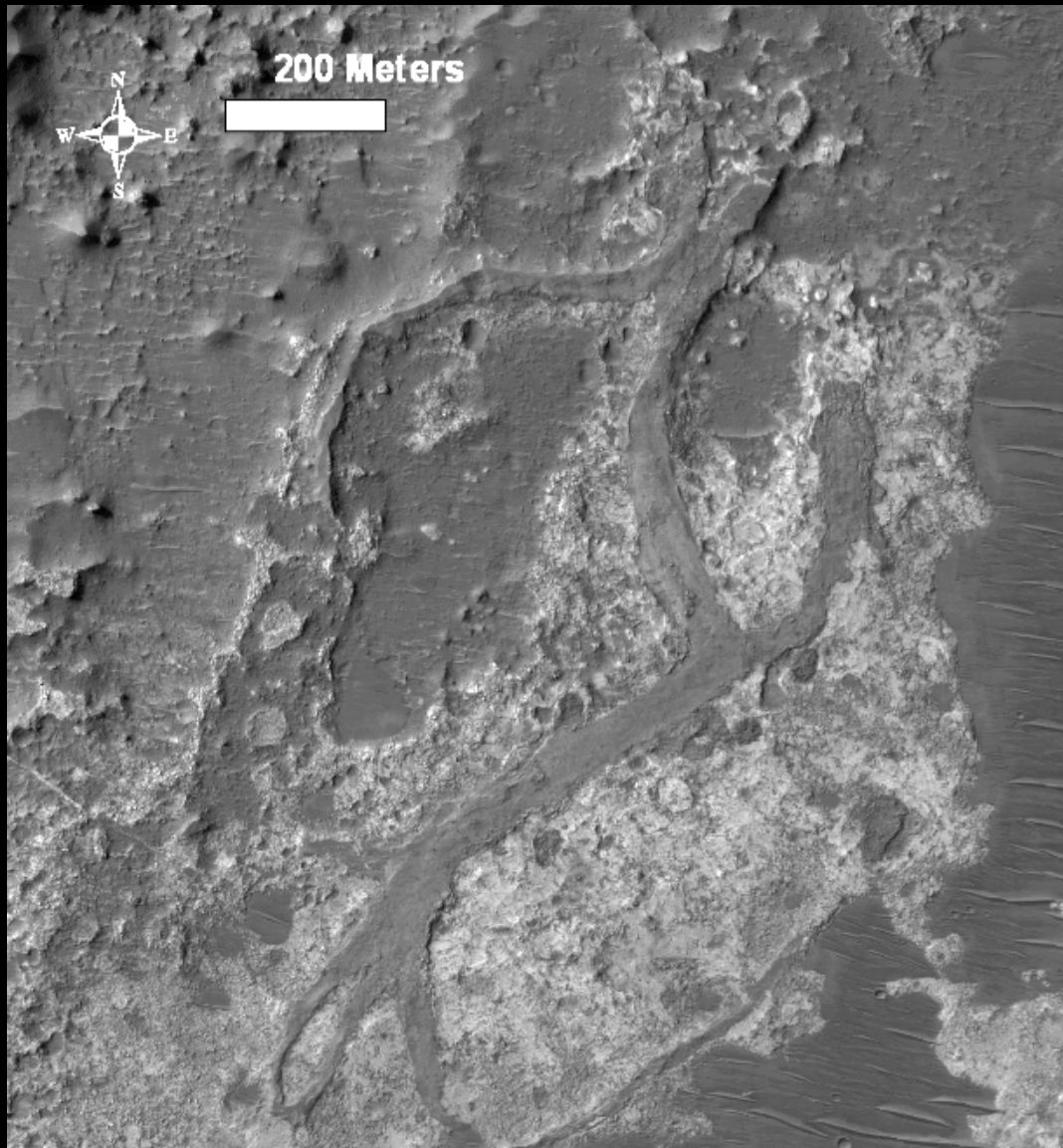
units

contacts

mineralogy

traverses

# 5. Sinuous Ridges



HiRISE image PSP\_010553\_1560

context

units

contacts

mineralogy

traverses



# Distribution of Sinuous Ridges

MOLA map stretched to show topographic variations within the Eberswalde basin

Thick blue lines are major drainage systems

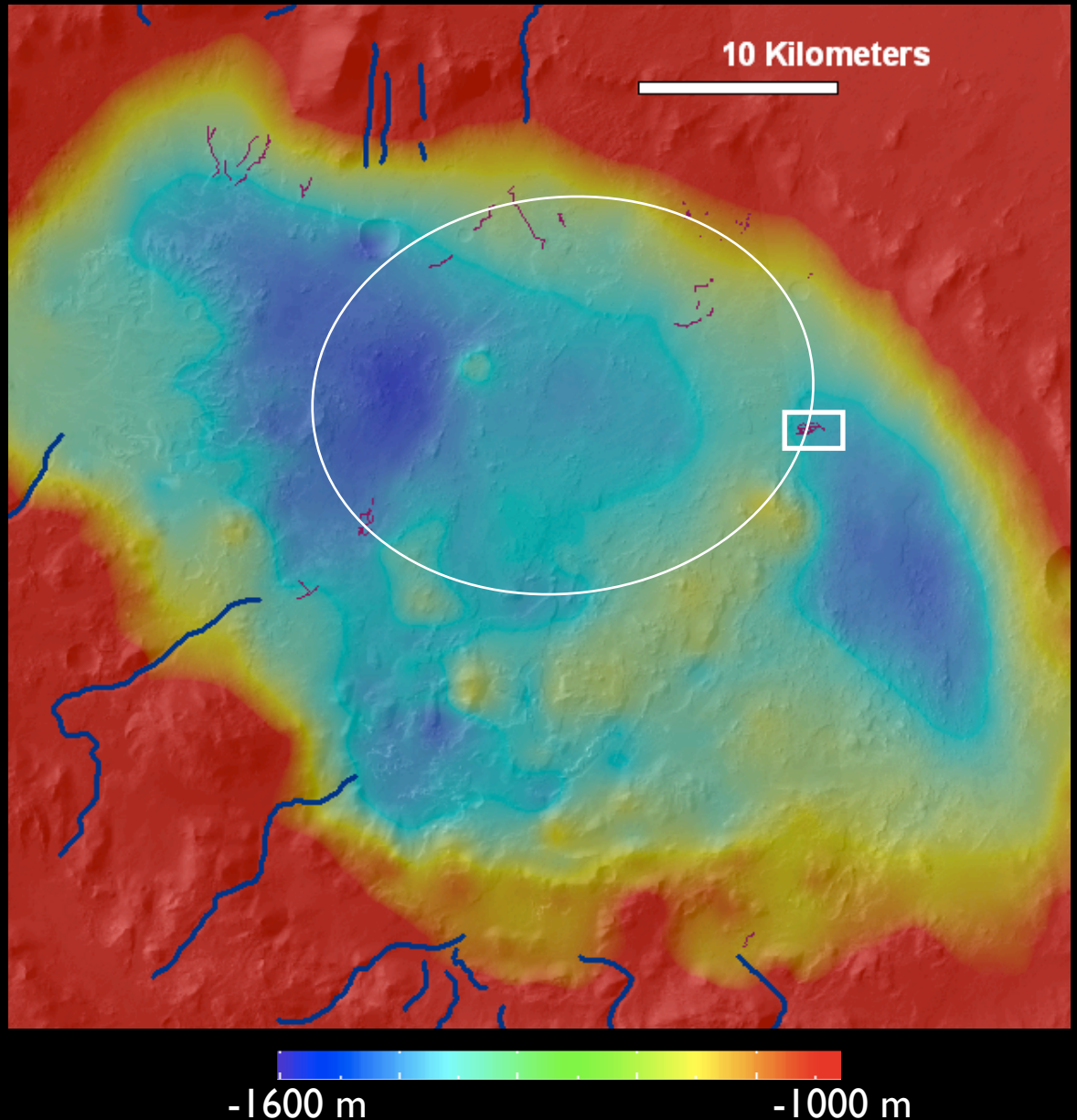
Thin purple lines are features interpreted as inverted channels (Scheiber et al., 2008; Rice et al., 2010)

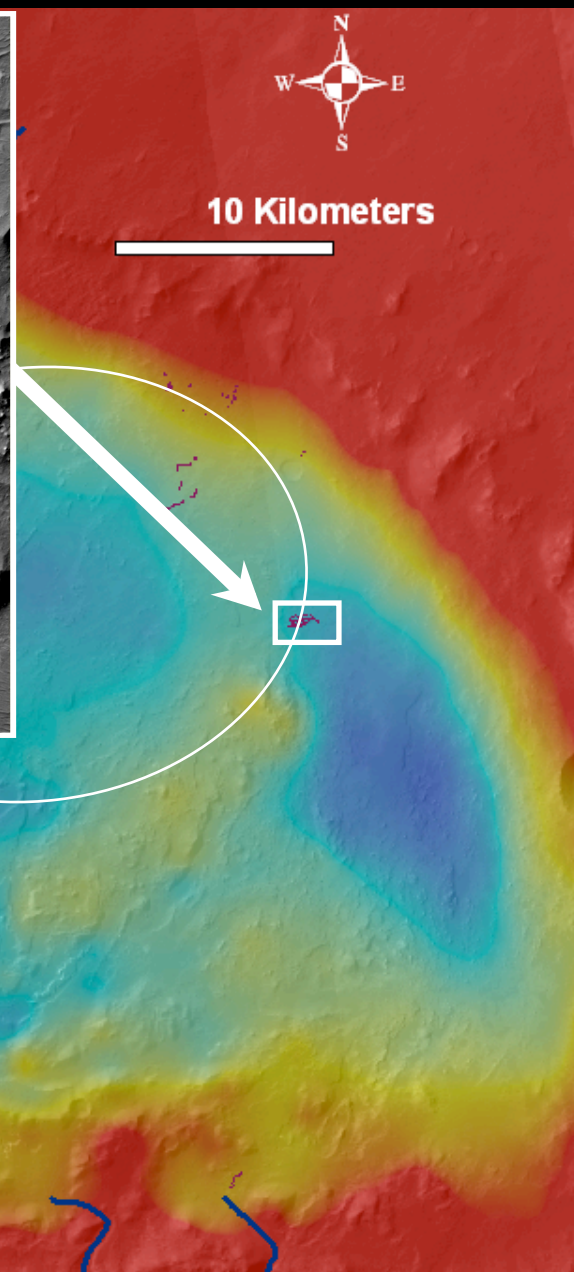
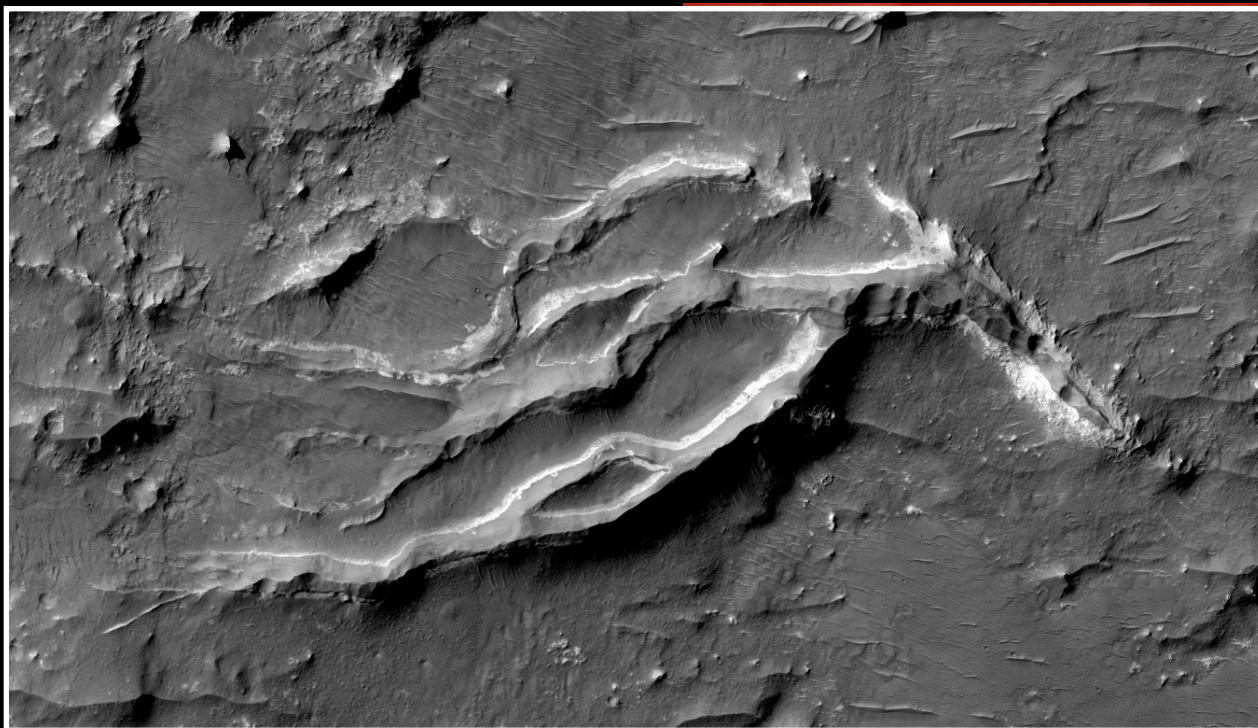
## Observations:

all channels but one lead from higher elevation crater rim to floor

one channel (white box) leads from interior ridge to eastern floor

no other potential fluvial features yet observed in eastern Eberswalde crater

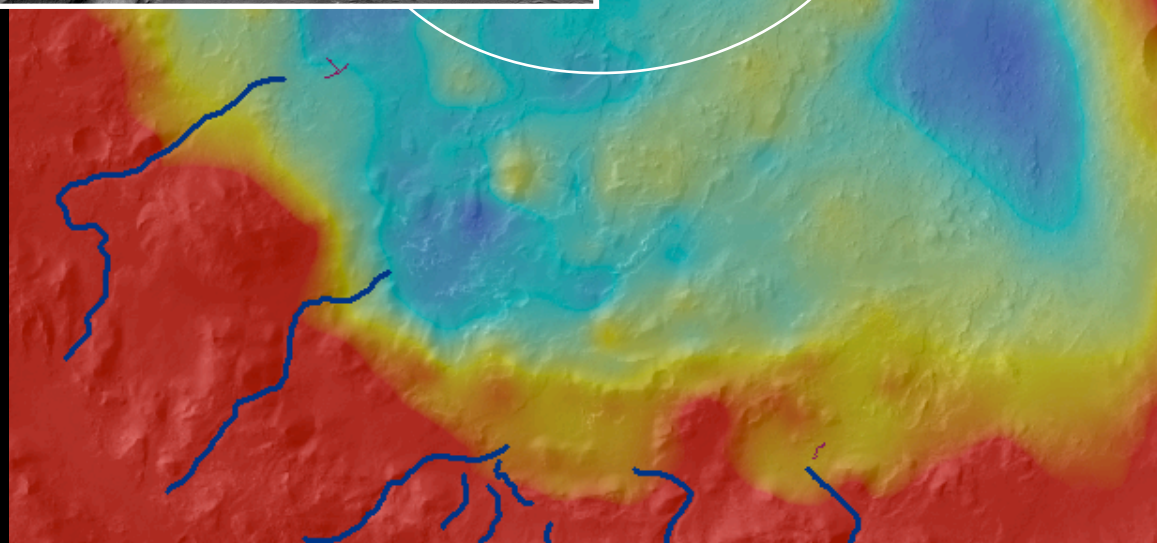




**Interpretations:**

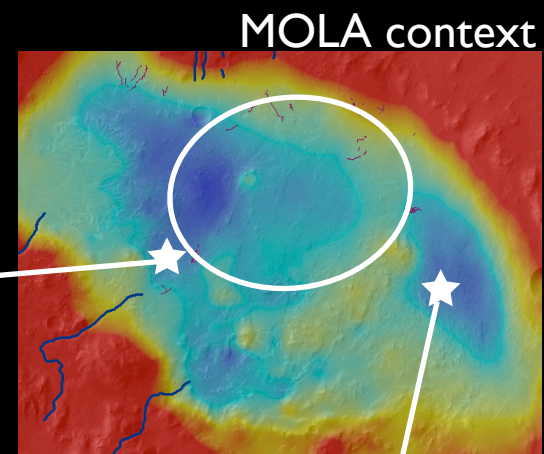
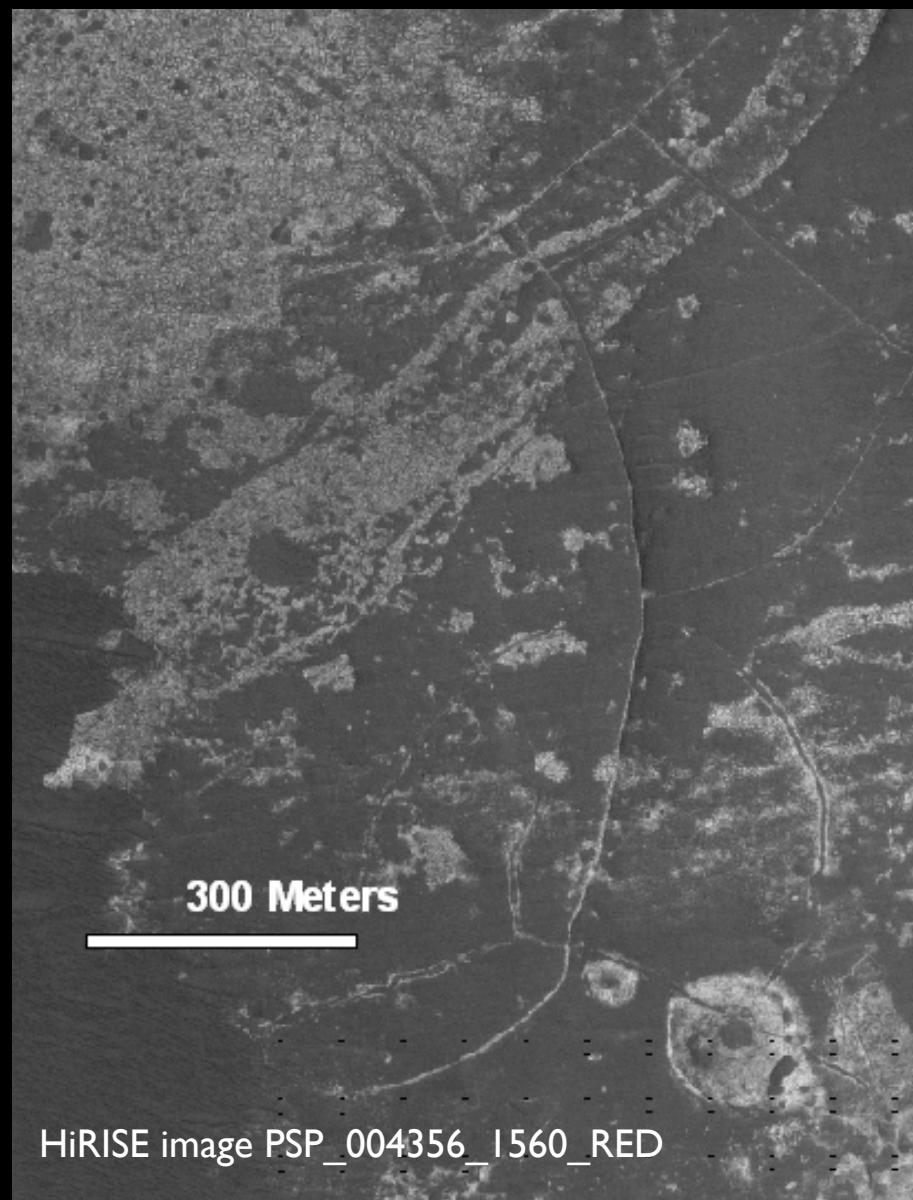
channel originates from ridge of interpreted as megabreccia from Holden ejecta

may be sourced from precipitation runoff, snowmelt, or the breach of a lake in western Eberswalde





## 6. Narrow vein-like features



context

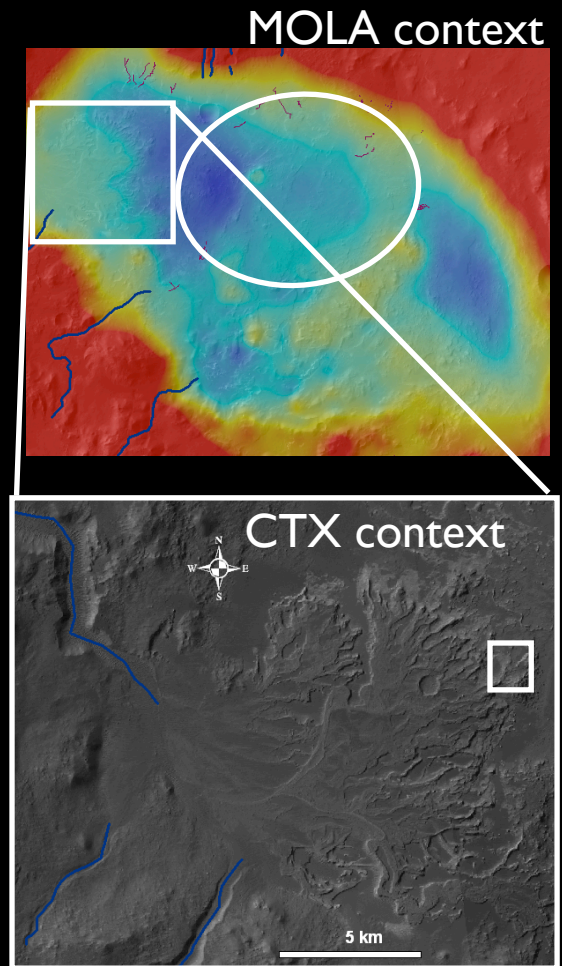
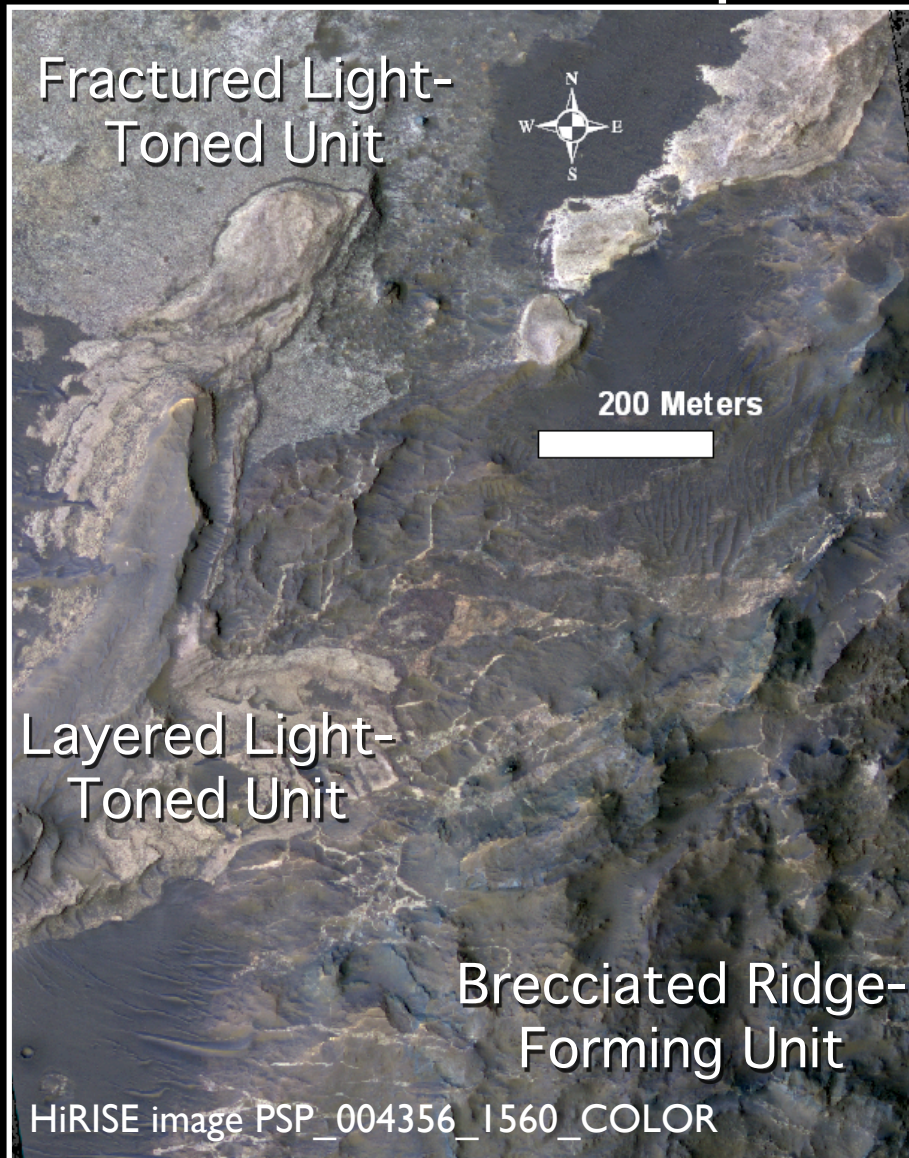
units

contacts

mineralogy

traverses

# Observed Relationships:



## Observations:

brecciated ridge-forming unit  
below both layered light-toned unit  
and fractured light-toned unit

context

units

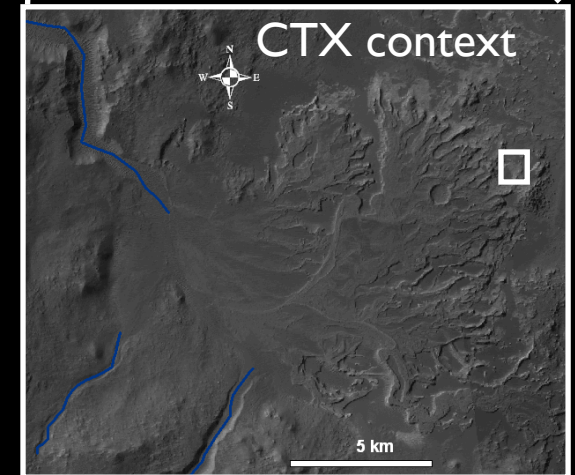
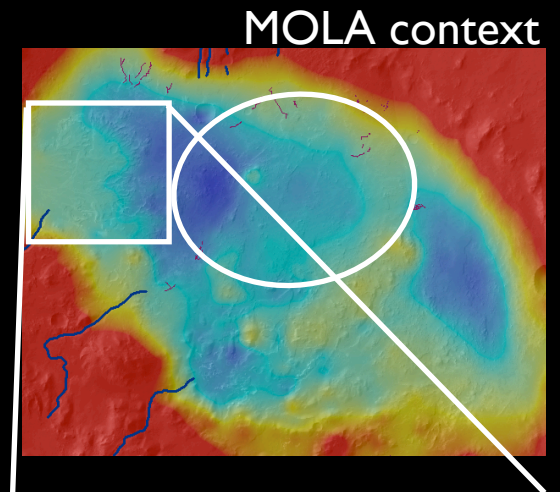
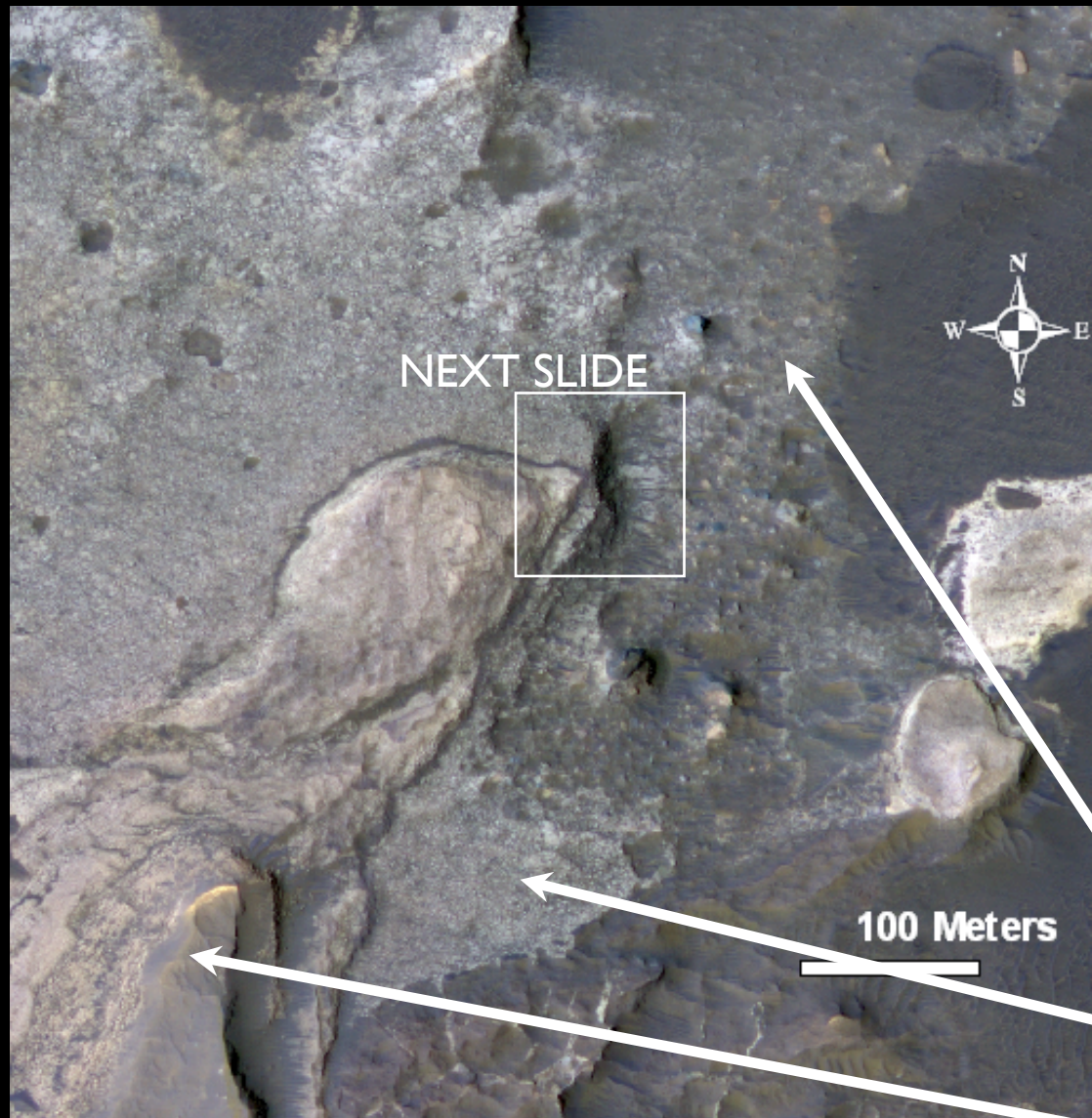
contacts

mineralogy

traverses



# Observed Relationships:



- discontinuous light-toned unit
- below fractured light-toned unit
- below light-toned layered unit

context

units

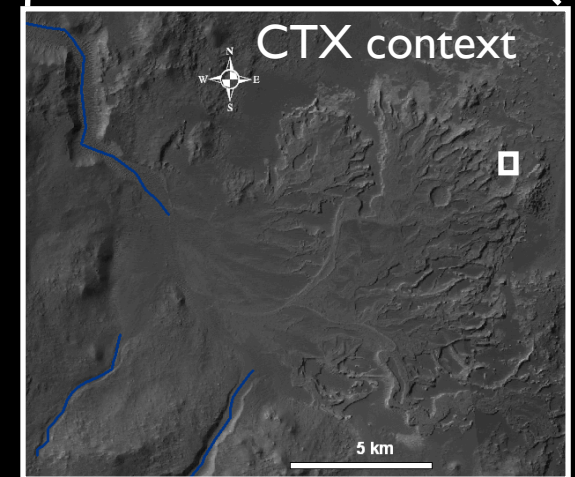
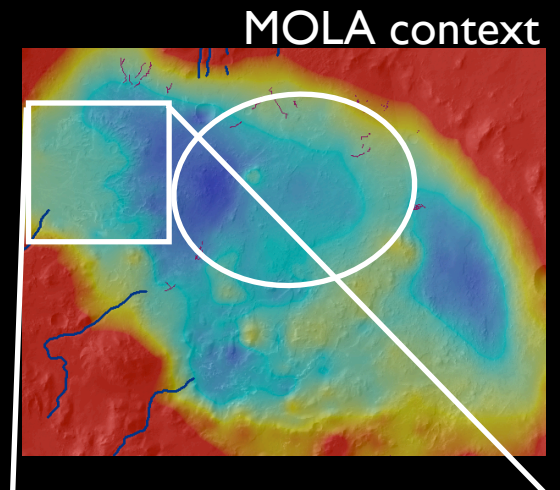
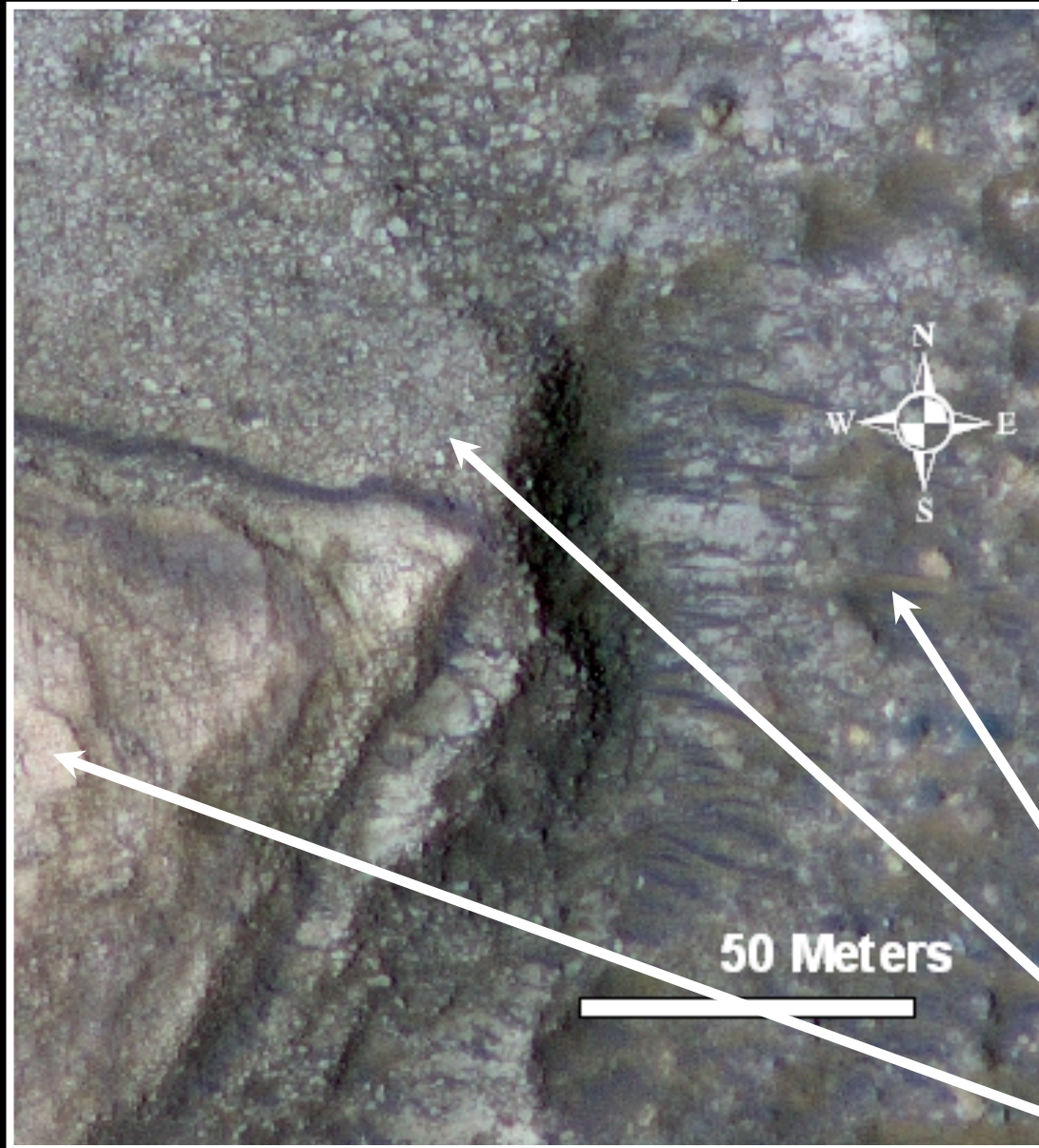
contacts

mineralogy

traverses



# Observed Relationships:



discontinuous light-toned unit

below fractured light-toned unit

below light-toned layered unit

context

units

contacts

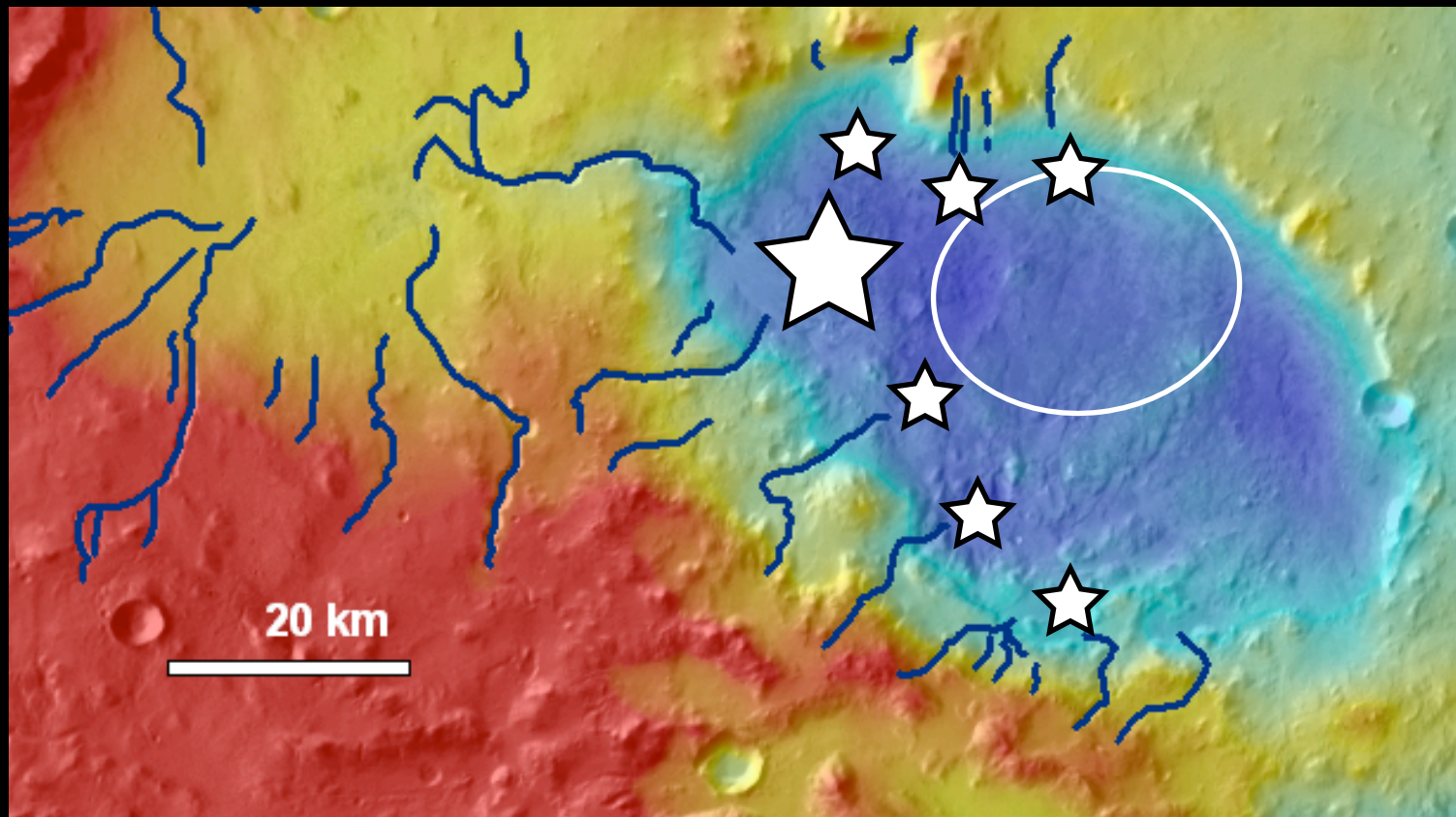
mineralogy

traverses



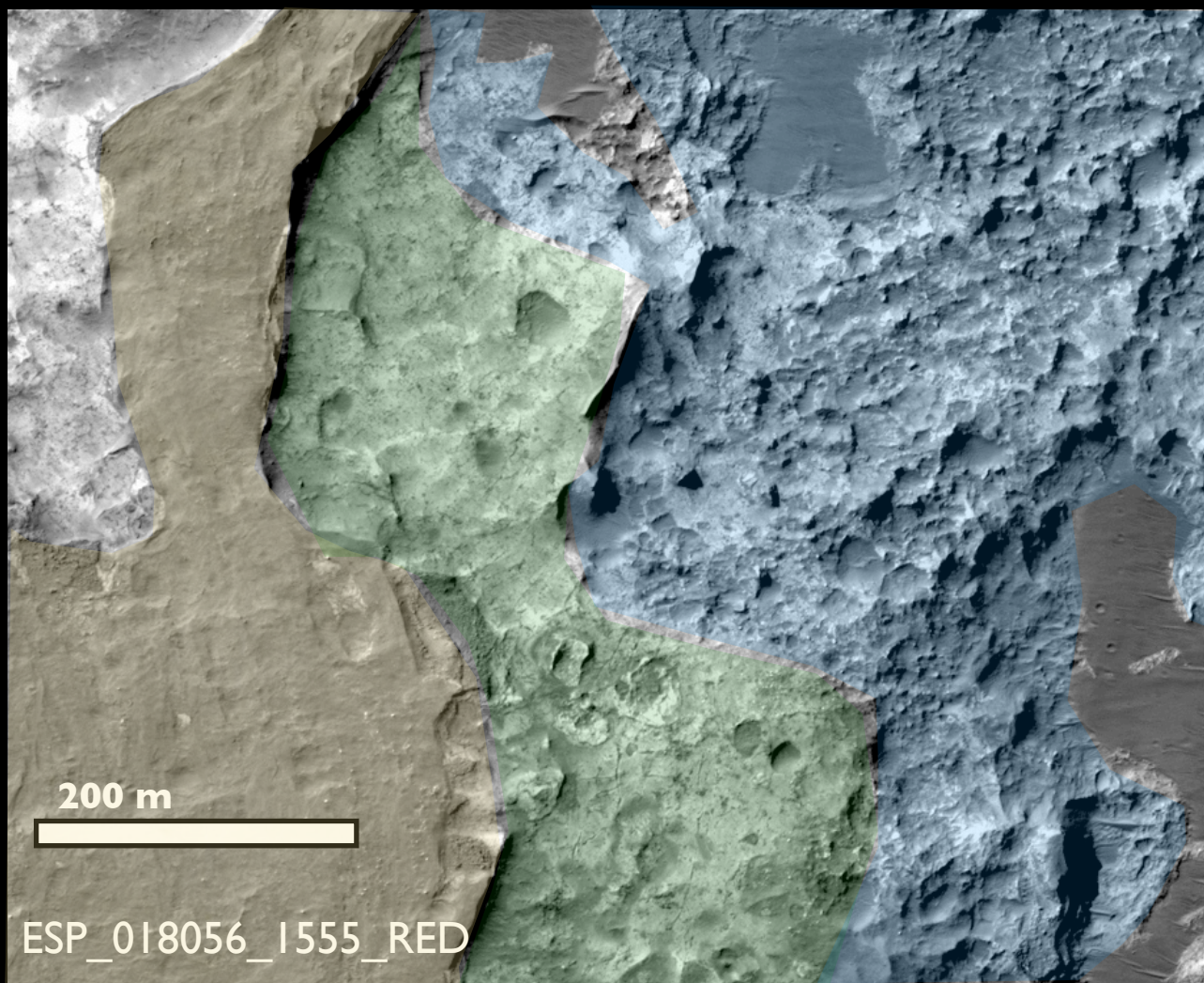
7 drainage systems, across the north, south and west rims of Eberswalde Crater, appear to be associated with the same stratigraphic sequence:

top: light-toned layered rock unit  
middle: polygonally fractured rock unit  
bottom: discontinuous, light-toned rock unit



-1600 m 0 m  
MOLA elevation





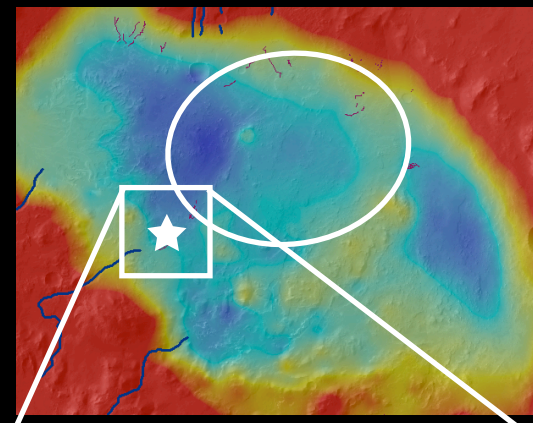
**Observations:**

discontinuous light-toned unit

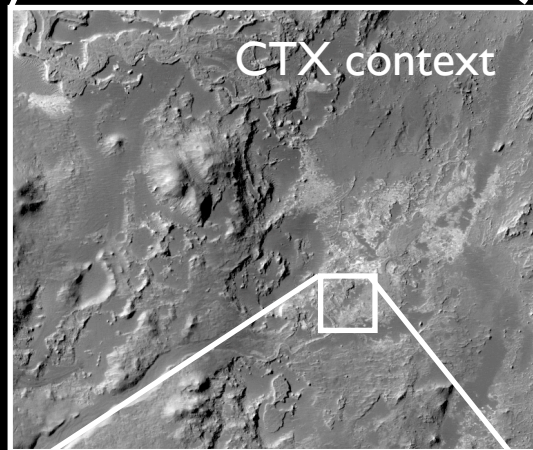
below fractured light-toned unit

below layered unit

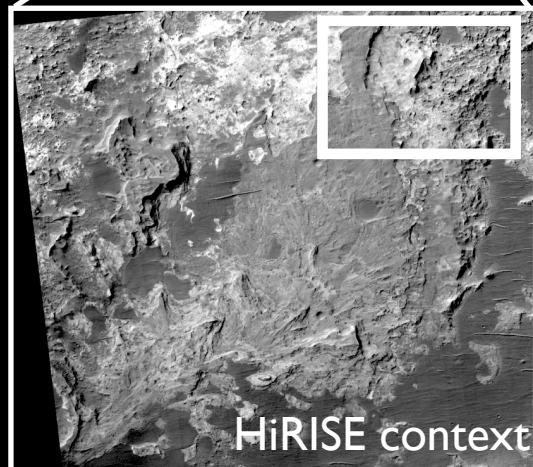
MOLA context



CTX context

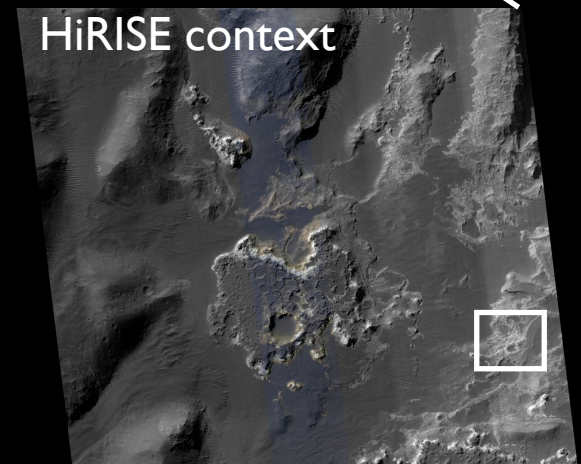
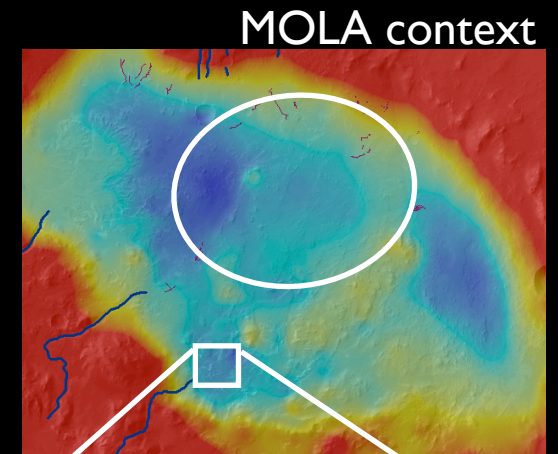
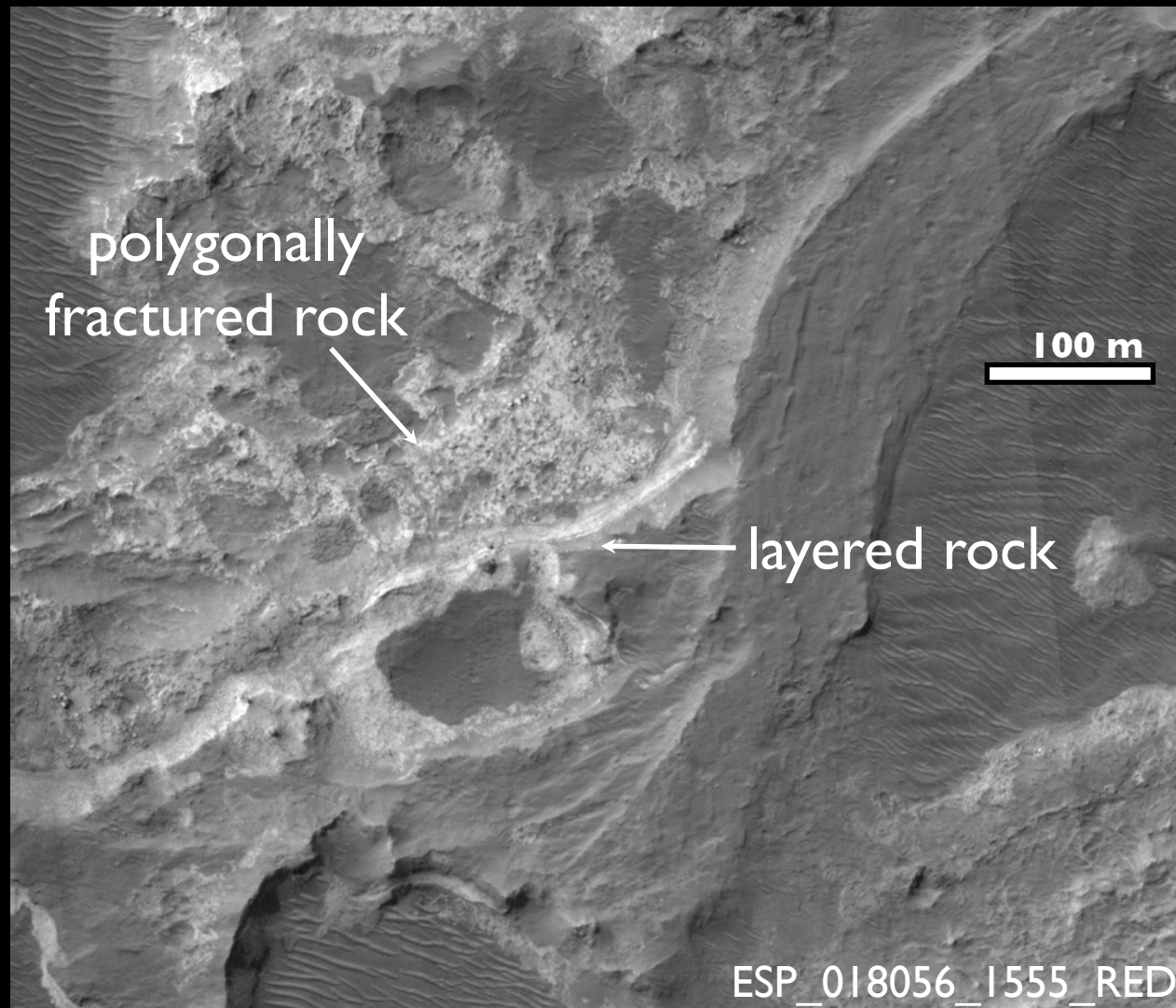


HiRISE context





# Observed Relationships:



**Observation:**  
sinuous, inverted ridges of  
light-toned, layered rock  
above light-toned, polygonally  
fractured unit

context

units

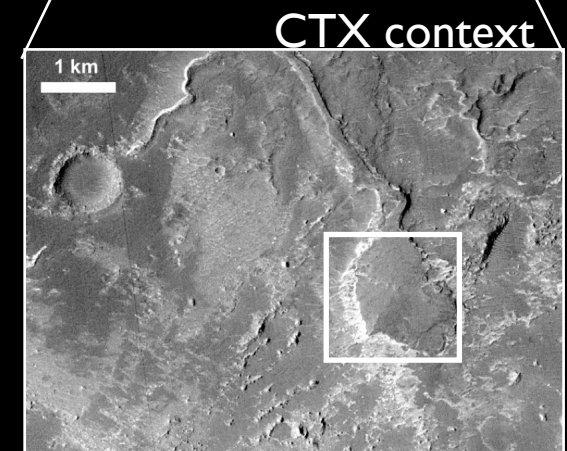
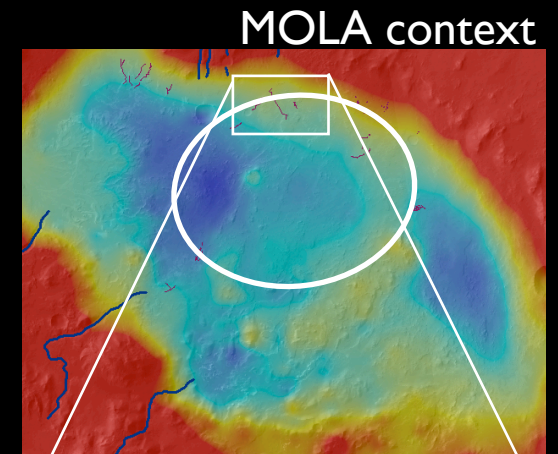
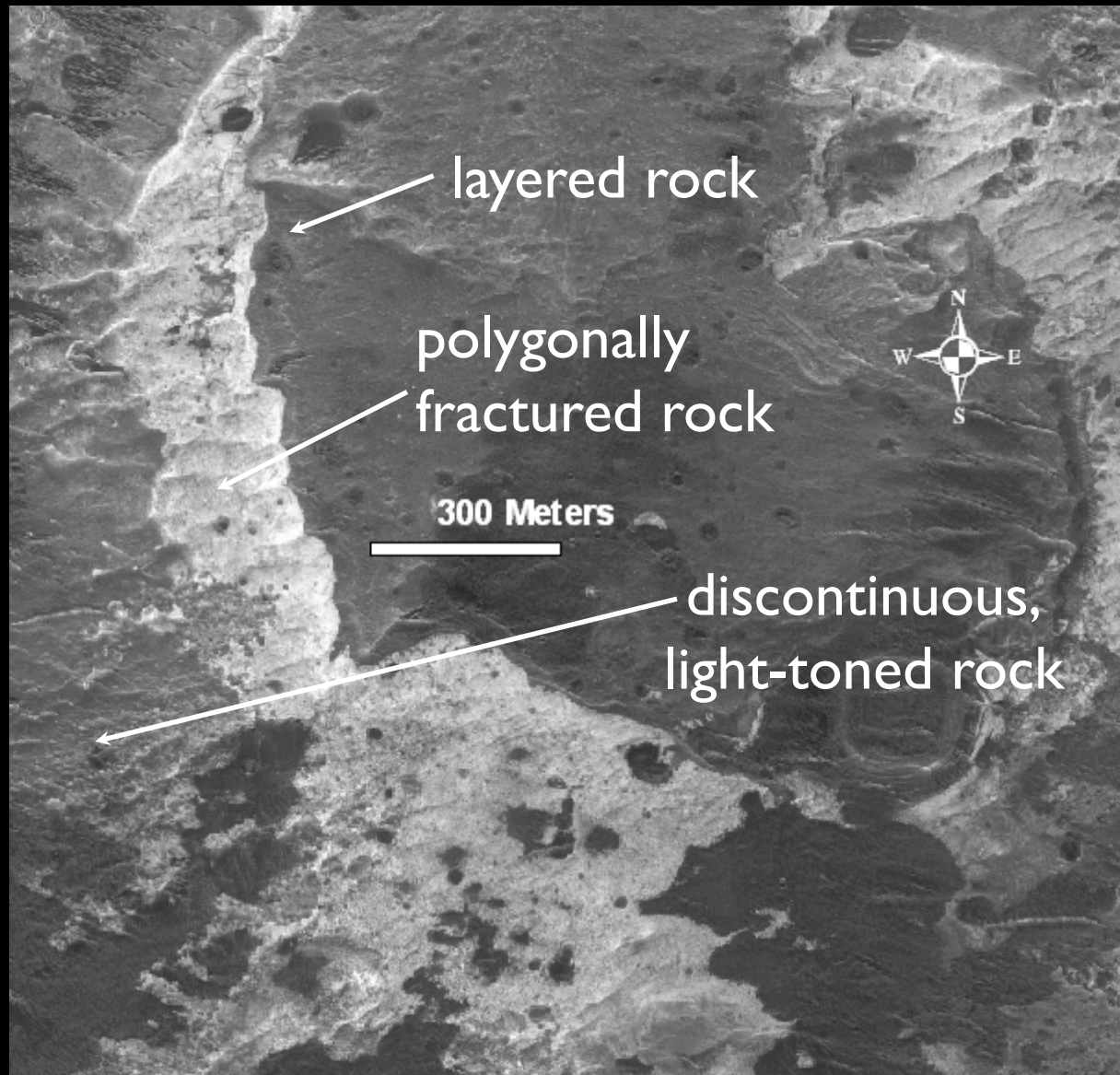
contacts

mineralogy

traverses



# Observed Relationships:



## Observations:

layered light-toned rock  
above polygonally fractured  
unit

*in landing ellipse*

context

units

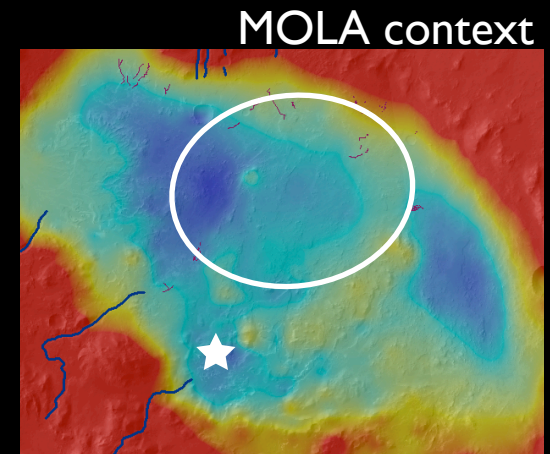
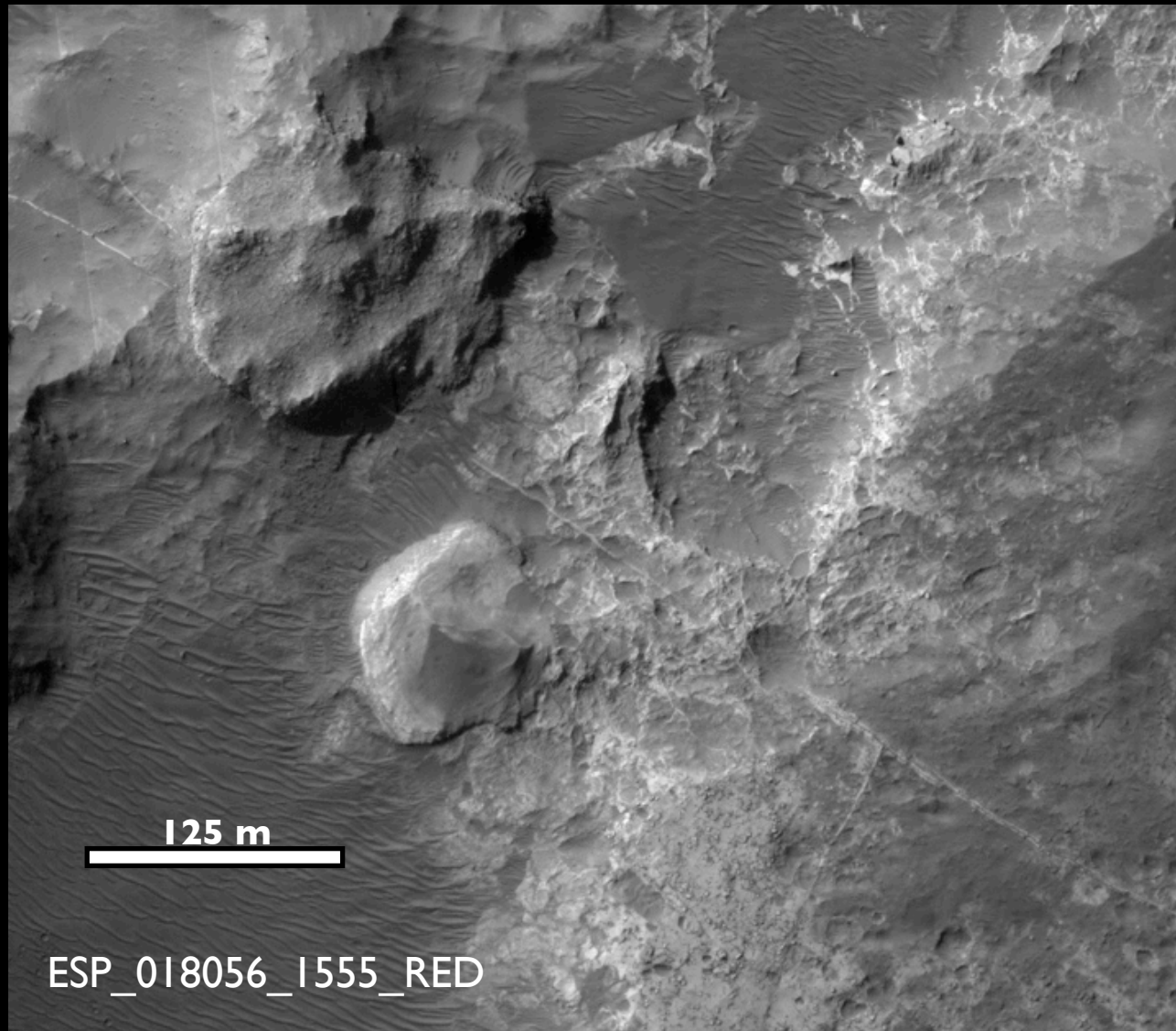
contacts

mineralogy

traverses



# Observed Relationships:



## Observation:

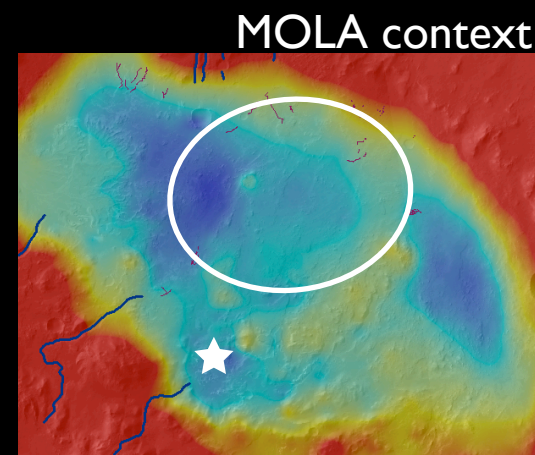
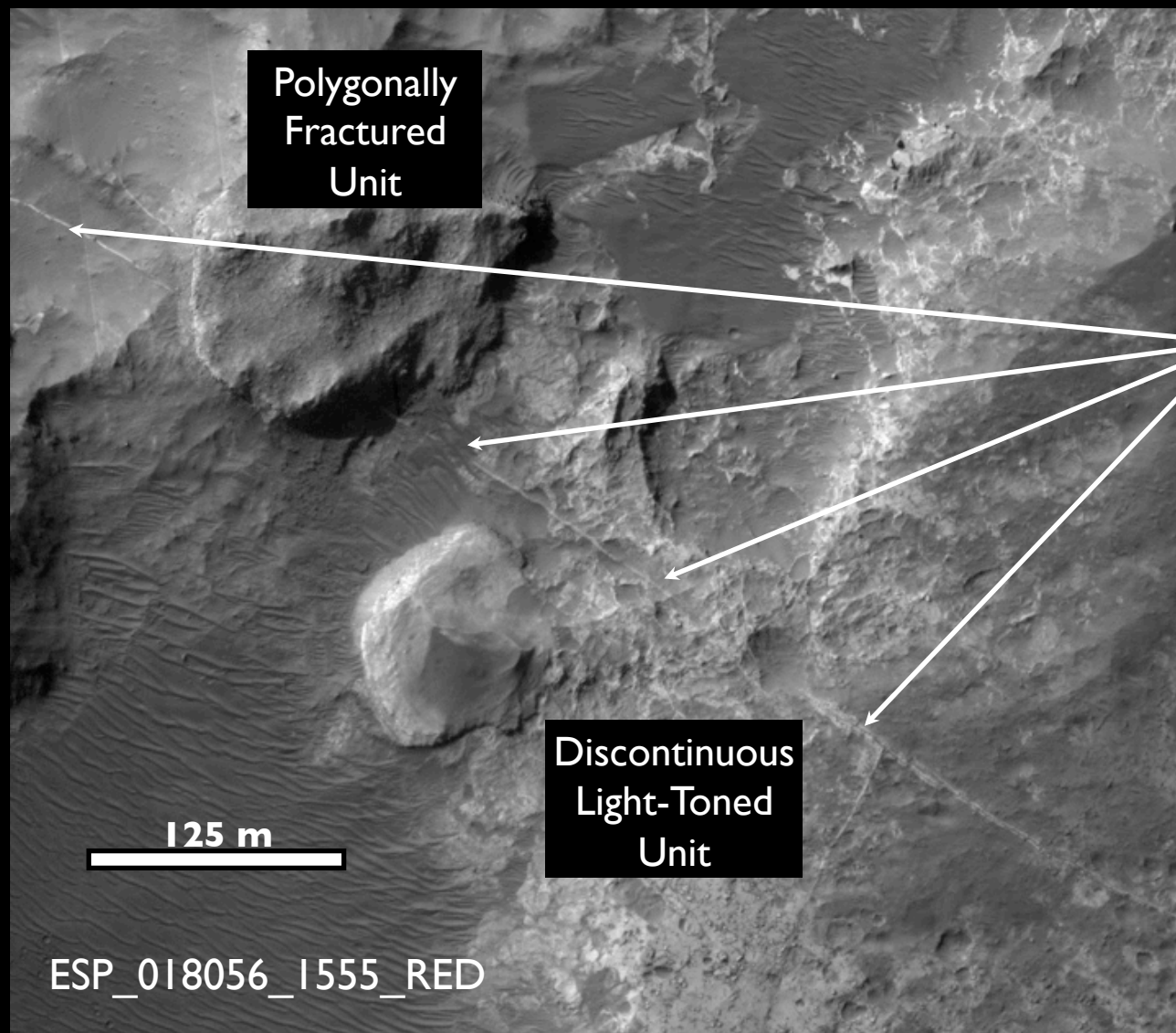
linear ridge cuts  
discontinuous, light-toned  
unit, but not the polygonally  
fractured unit

## Interpretations:

the discontinuous, light-  
toned unit predates the  
deltaic/fluviol/lacustrine  
sediments

the discontinuous, light-  
toned unit may be fractured  
Eberswalde basement rock  
with light-toned fracture fill

# Observed Relationships:



## Observation:

linear vein-like feature cuts discontinuous, light-toned unit, but not the polygonally fractured unit

## Interpretations:

the discontinuous, light-toned unit predates the deltaic/fluvial/lacustrine sediments

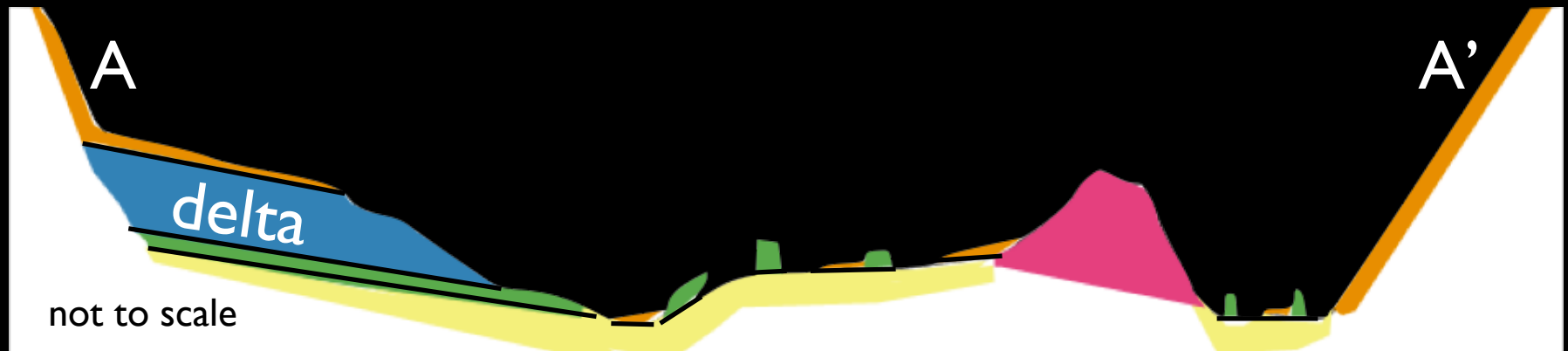
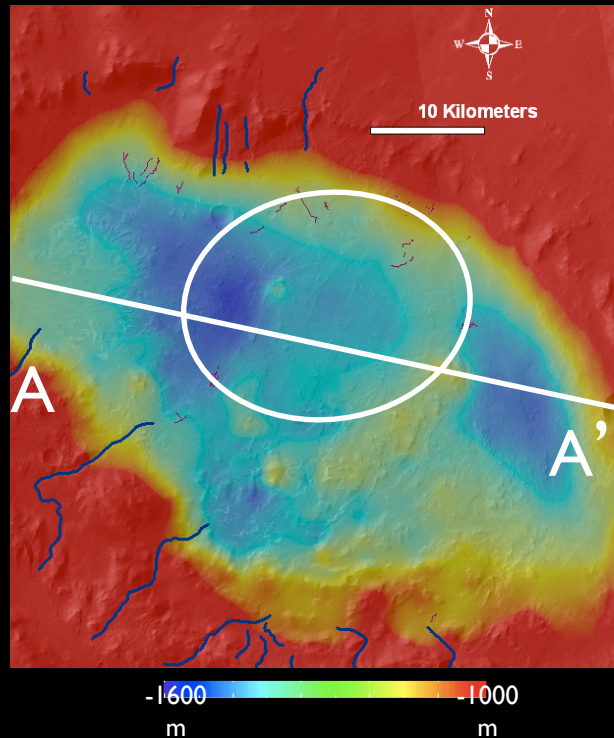
the discontinuous, light-toned unit may be fractured Eberswalde basement rock with light-toned fracture fill



# Cartoon Cross-Section of Eberswalde:

## Photostratigraphic Units:

- Mantling unit
- Layered light-toned unit
- Fractured light-toned unit
- Discontinuous light-toned unit
- Brecciated ridge-forming unit



context

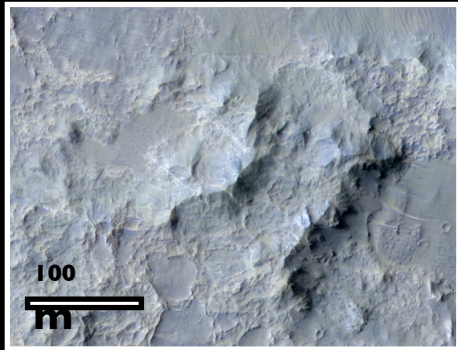
units

contacts

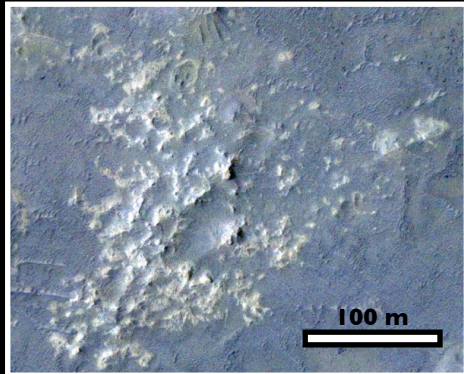
mineralogy

traverses

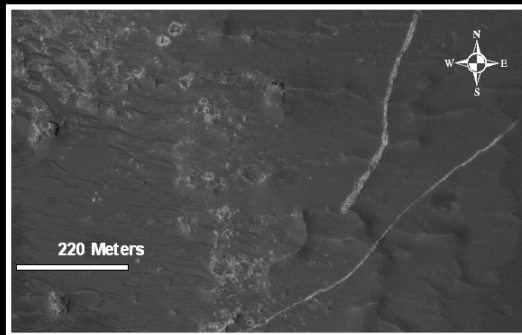
# Depositional Hypotheses:



**brecciated ridge-forming unit** could correspond to megabreccia from the Holden and Eberswalde impacts



**discontinuous, light-toned rock unit** has previously been interpreted as lacustrine sediments (Pondrelli *et al.*, 2008), but could instead be eroded megabreccia or altered Eberswalde basement rock (*this unit is observed throughout the Eberswalde basin, no evidence for layering observed*)



**narrow, vein-like features** could be fracture-fill formed by the circulation of hydrothermal fluids

context

units

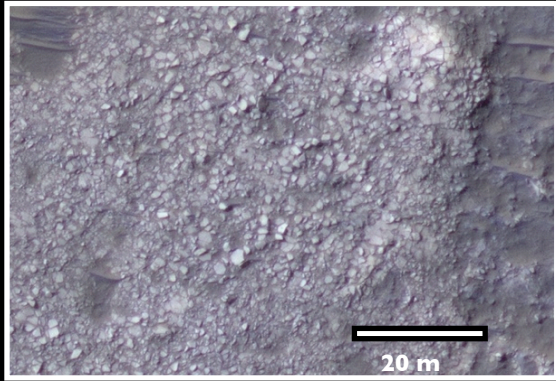
contacts

mineralogy

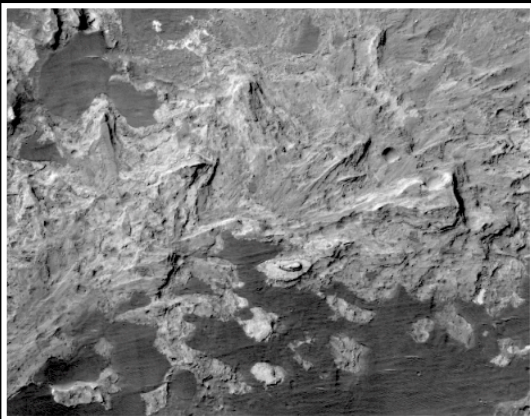
traverses



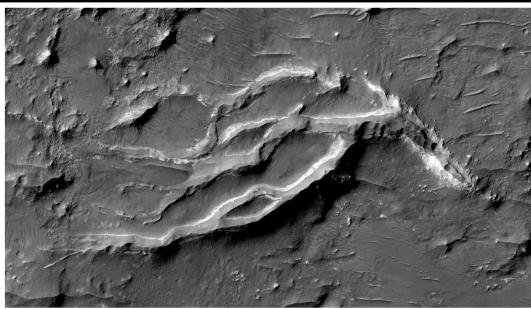
# Depositional Hypotheses:



**polygonally fractured rock unit** appears to be delta bottomsets and/or alluvial fan sediments and/or lacustrine sediments (*outcrops of this unit are also observed in the center and the eastern portion of the Eberswalde basin*)



**light-toned layered rock unit** appears to be remnants of deltas and/or alluvial fans (*no outcrops of this unit have been observed that are not associated with a drainage system*)



**sinuous ridges** appears to be inverted fluvial channels

context

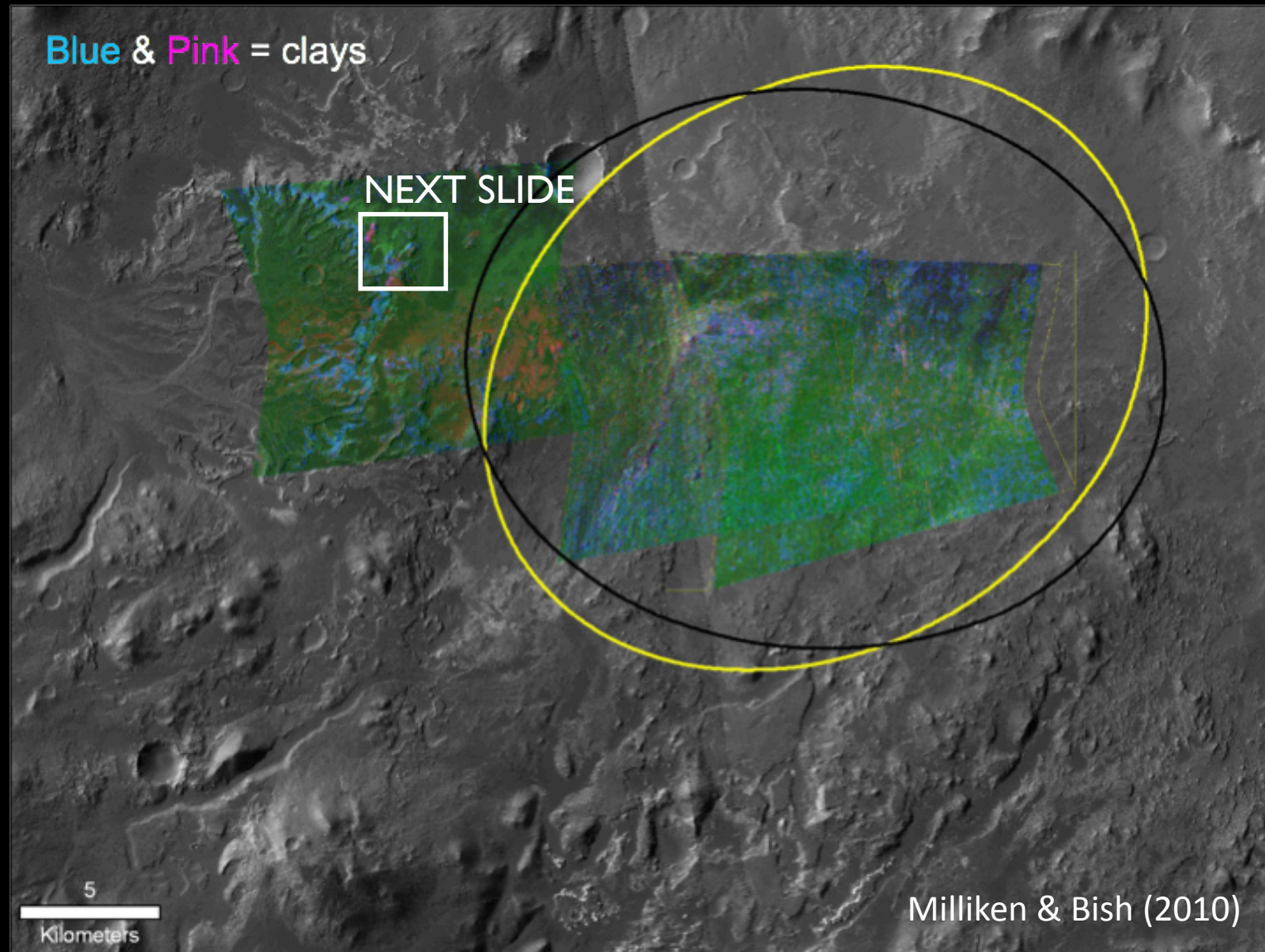
units

contacts

mineralogy

traverses

# Relationships to Mineralogic Units:



context

units

contacts

mineralogy

traverses



Evidence for two distinct clay mineral phases:

Clays w/ Pyroxene

Fe-rich Clays

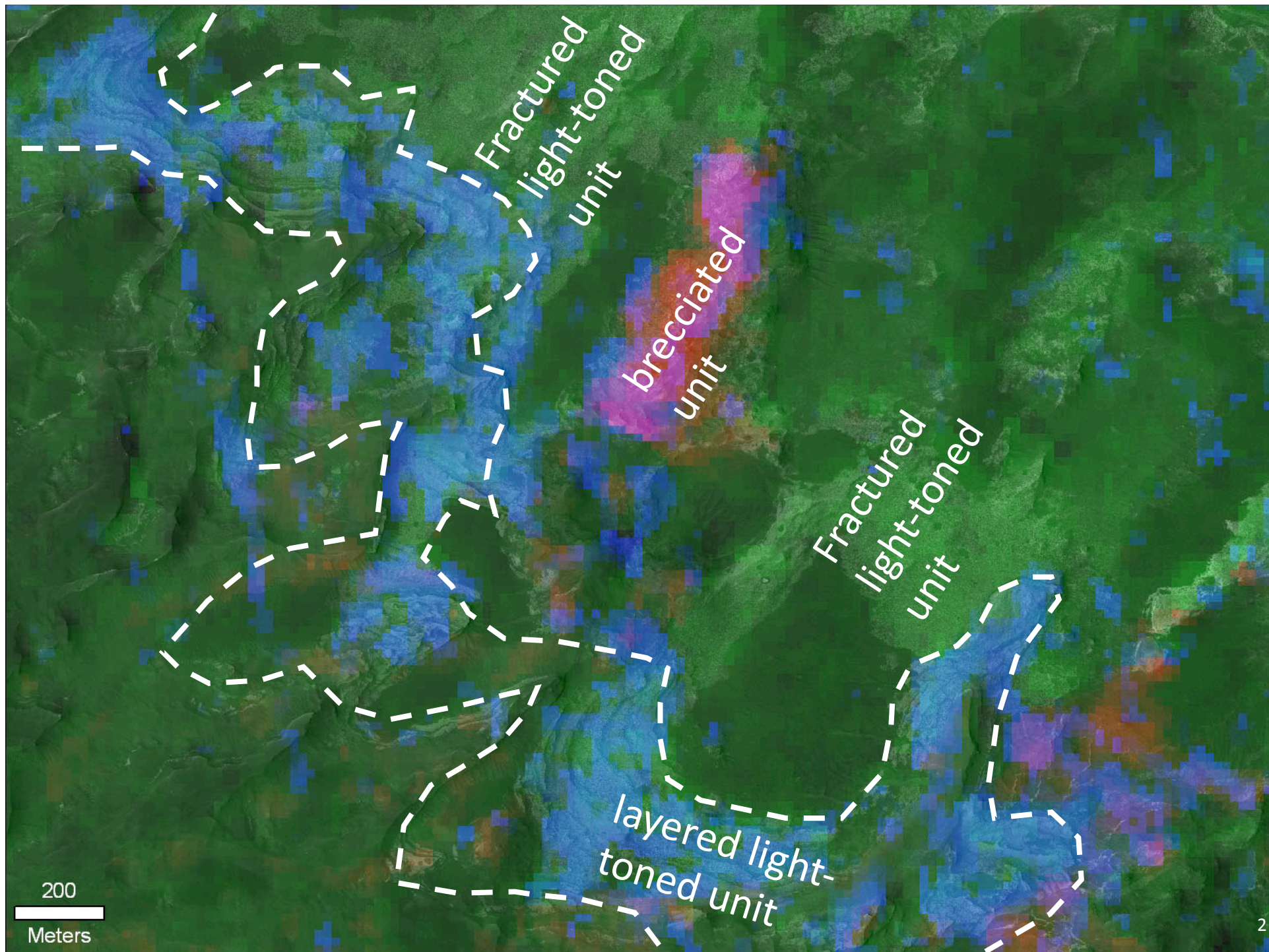
Pyroxene w/ Clays

200

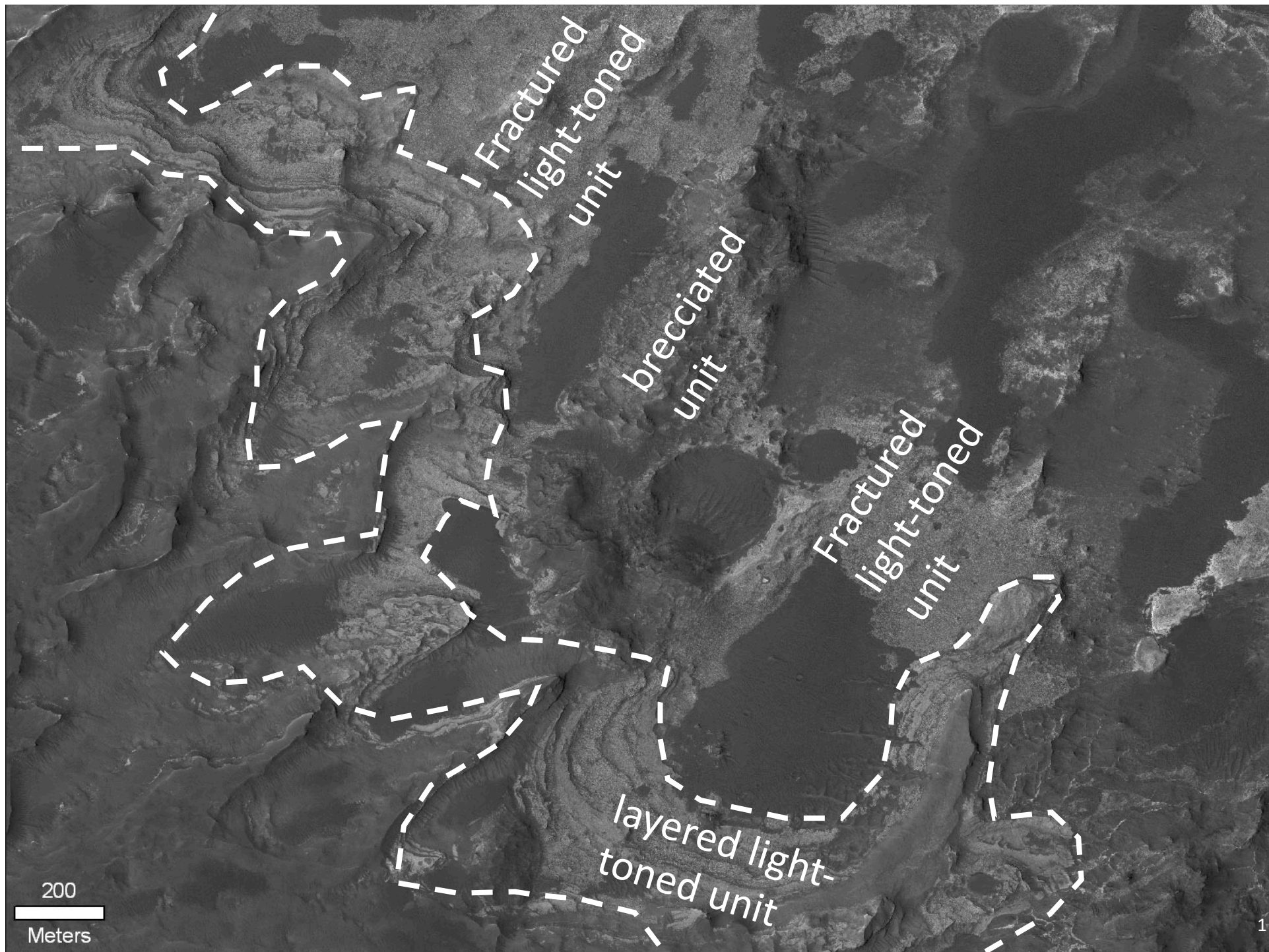
Meters

from Ralph Milliken's 4th Workshop Presentation, 9/27/2010



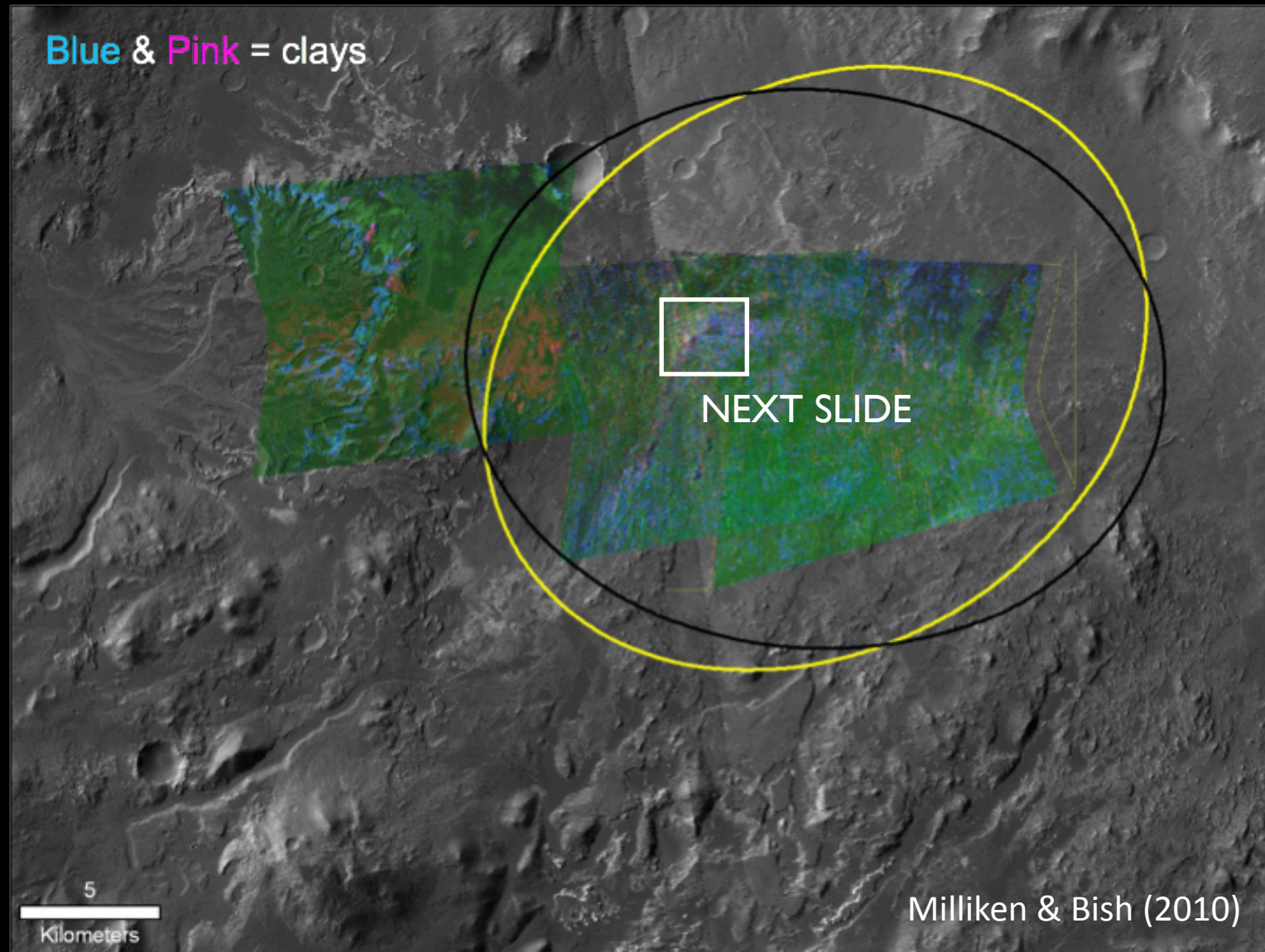








# Relationships to Mineralogic Units:



context

units

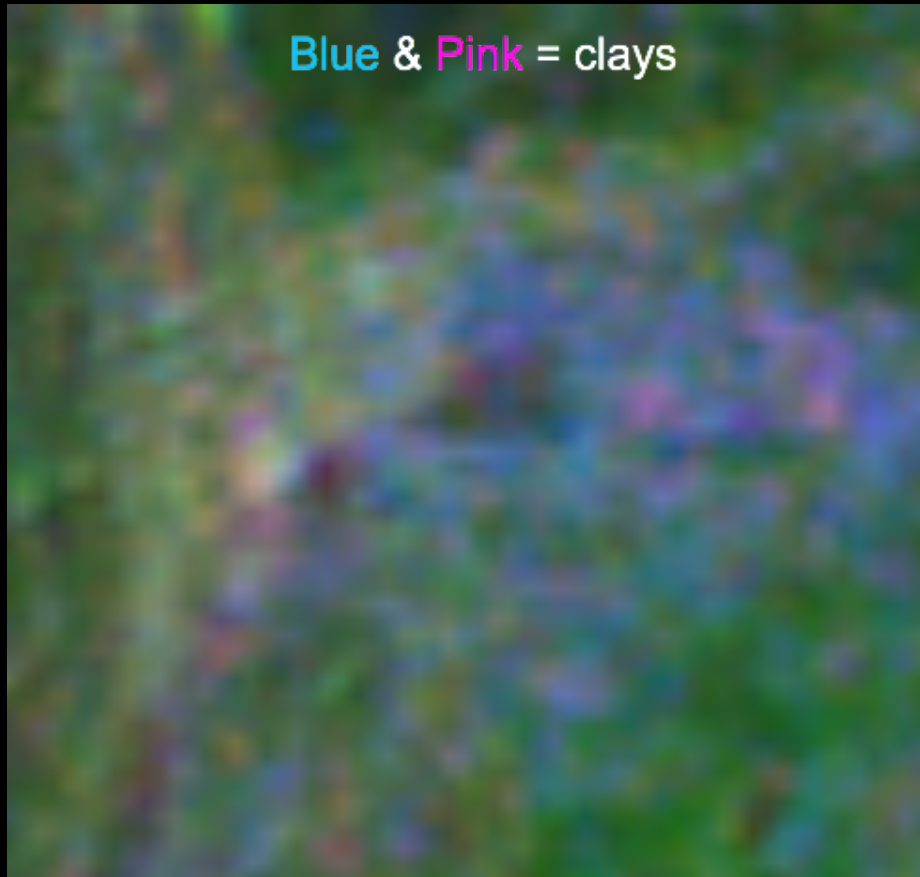
contacts

mineralogy

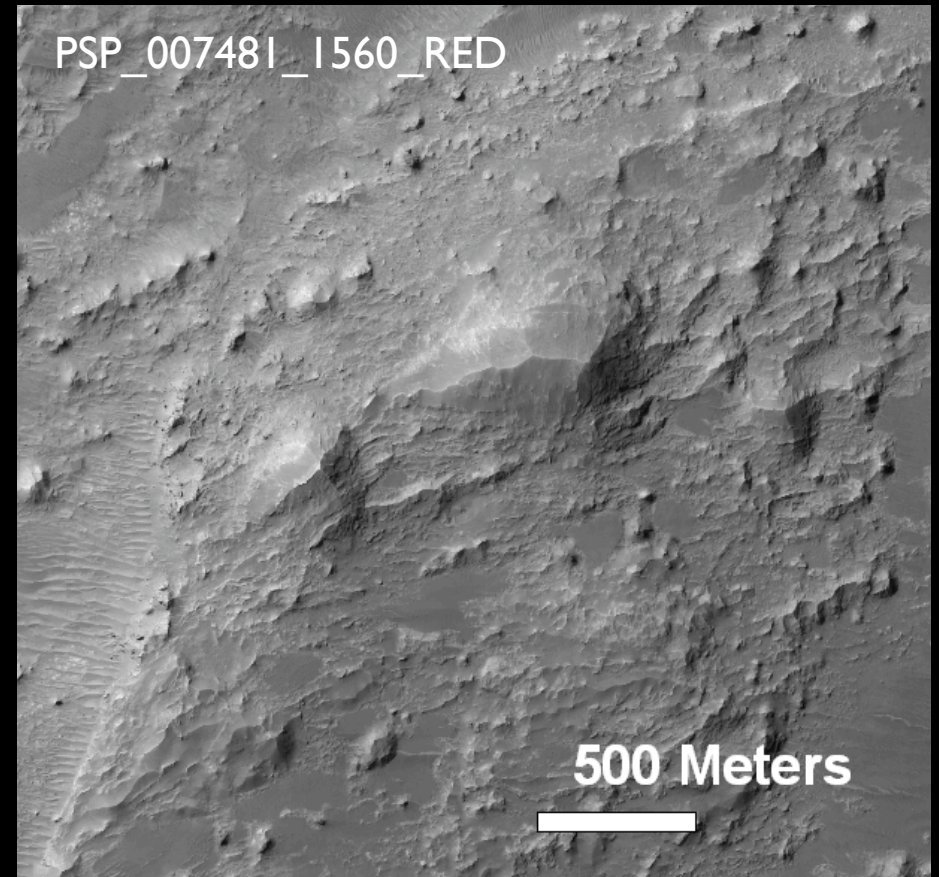
traverses



# Relationships to Mineralogic Units:



Milliken & Bish (2010)



*in the ellipse, clay mineral units  
correspond to the brecciated unit*

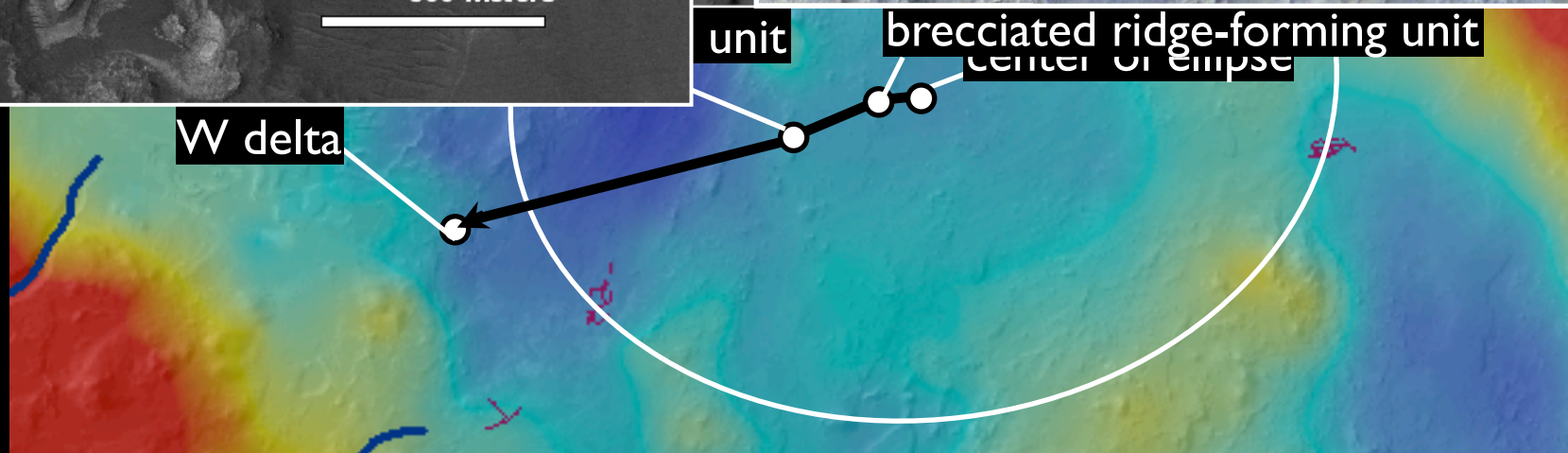
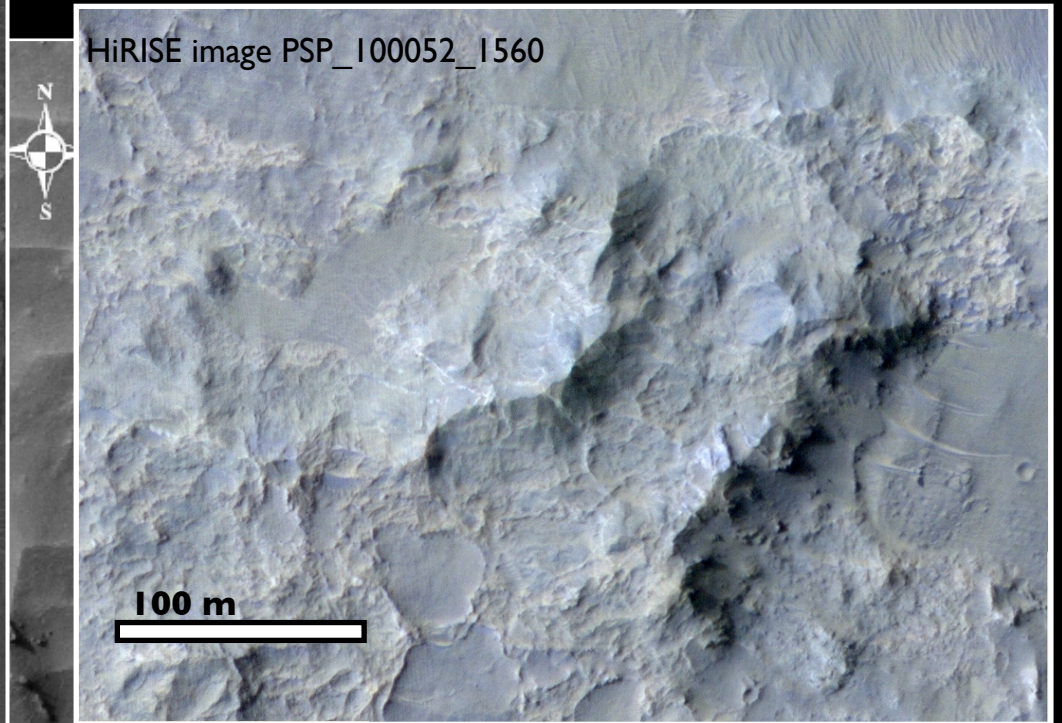
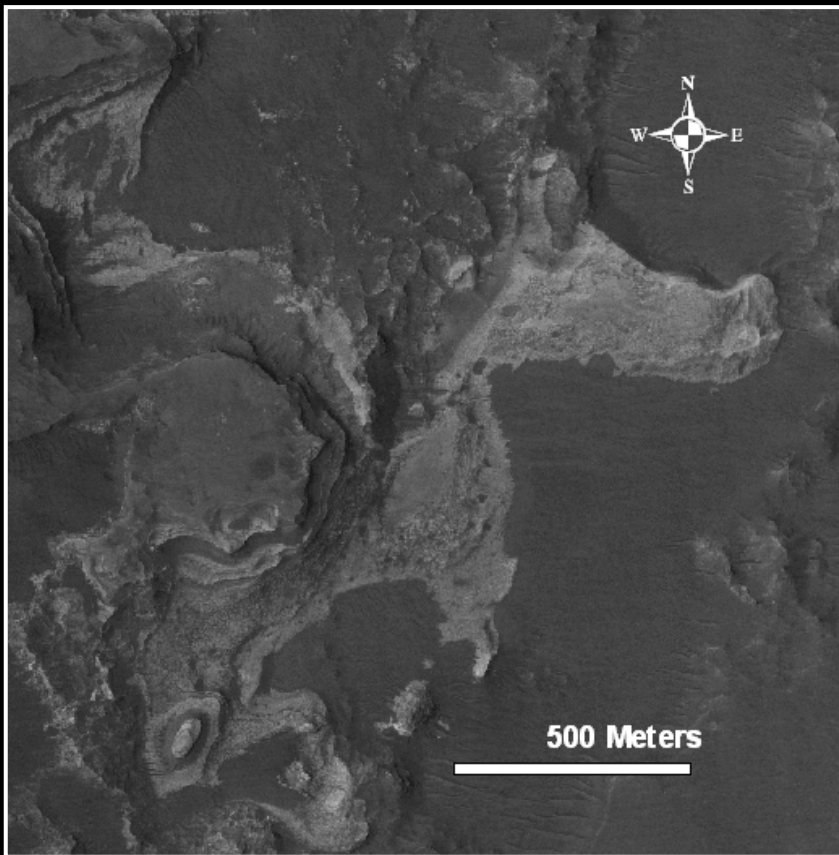
context

units

contacts

mineralogy

traverses



context

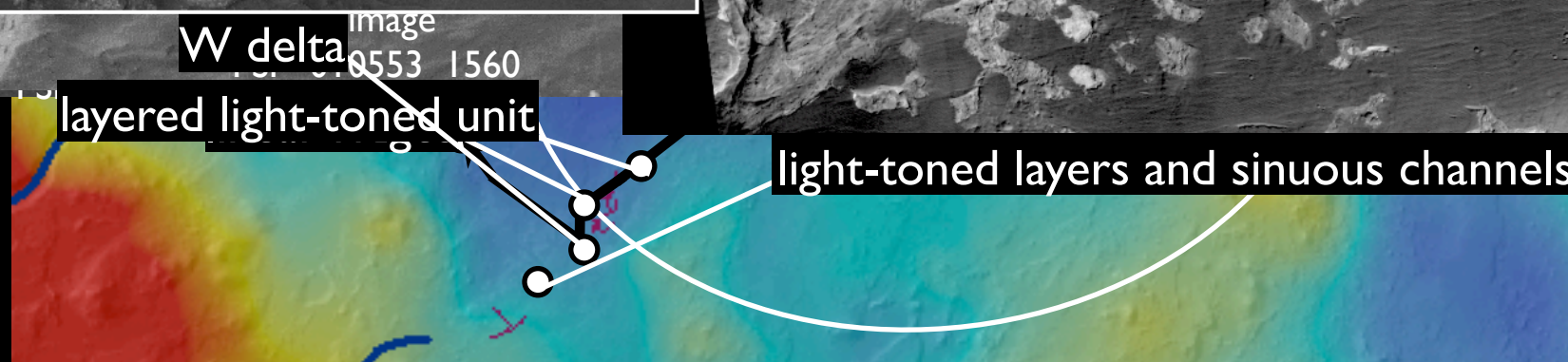
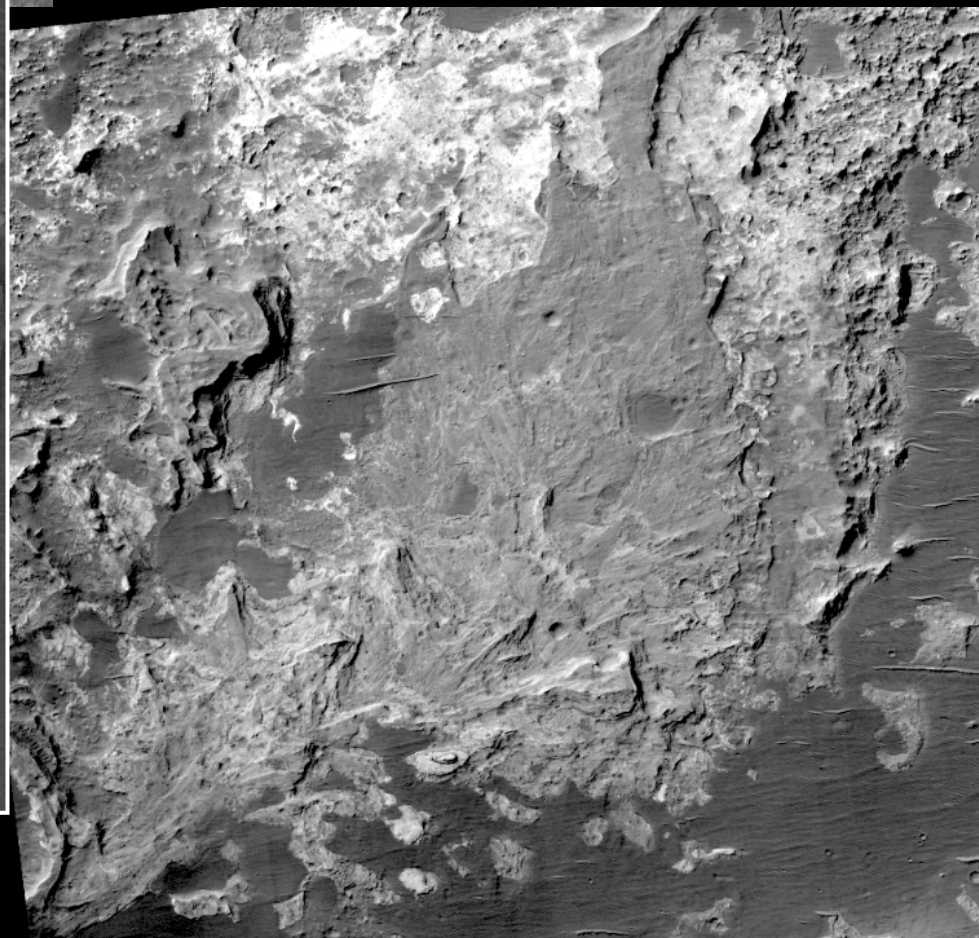
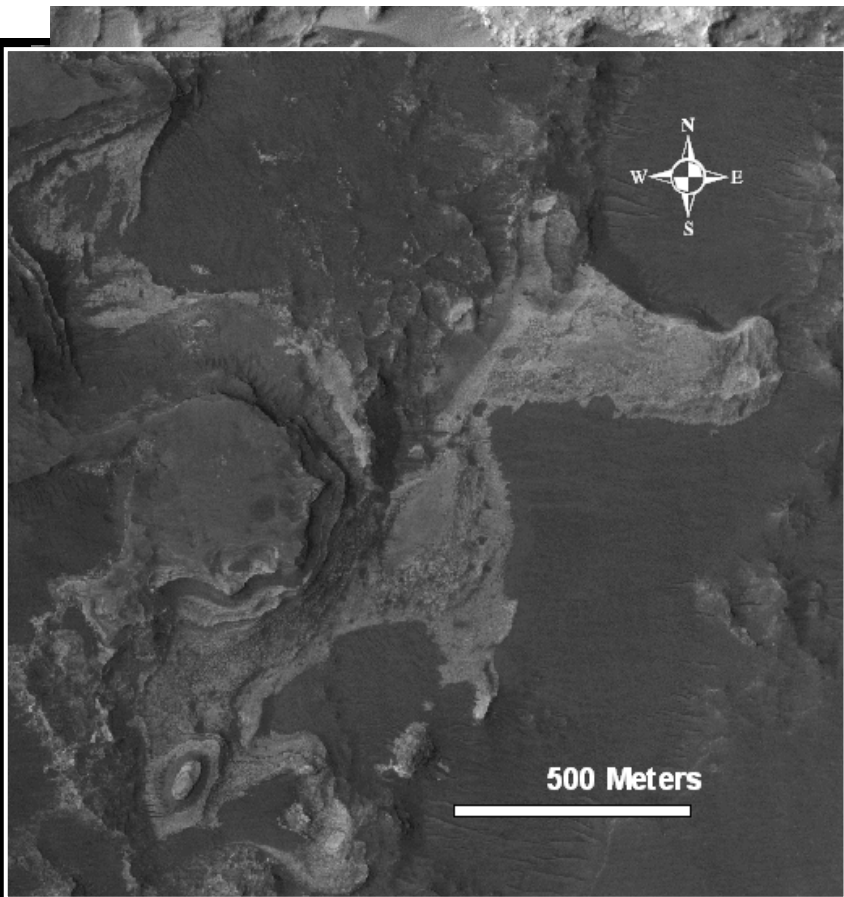
units

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mineralogy

traverses





context

units

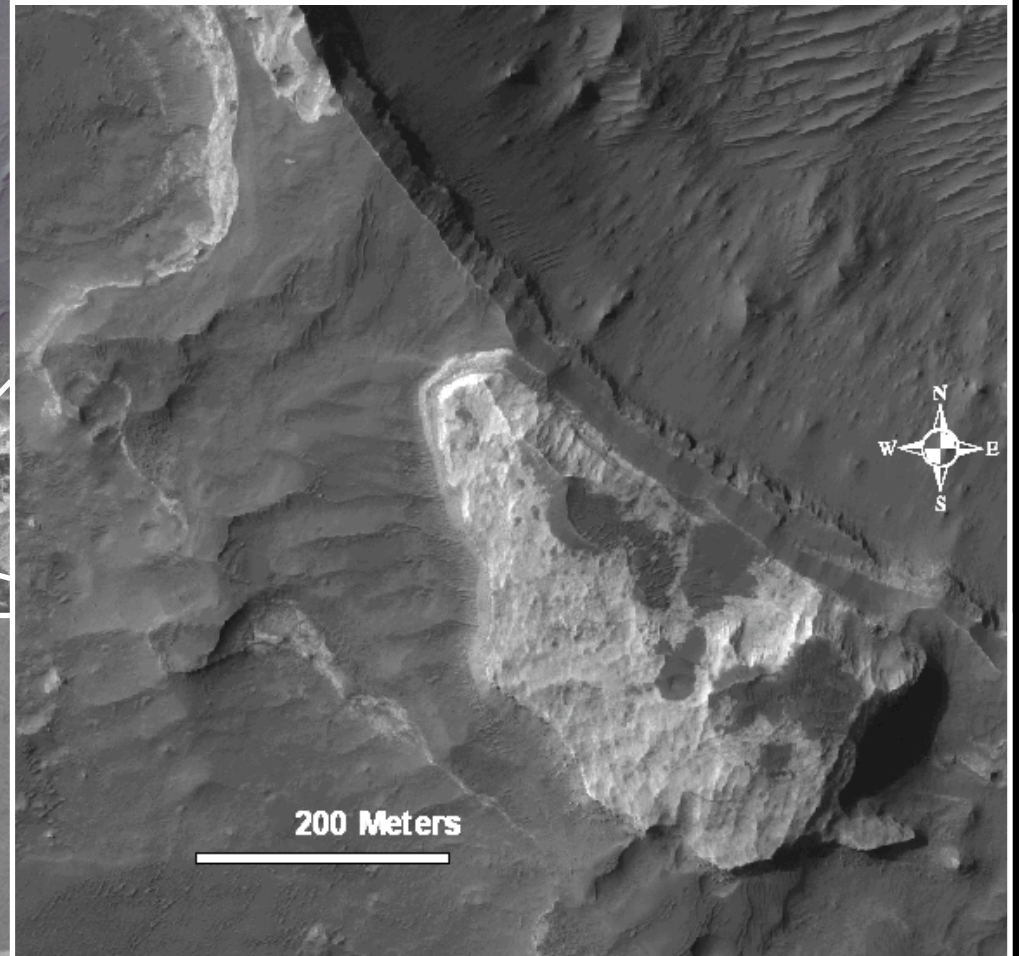
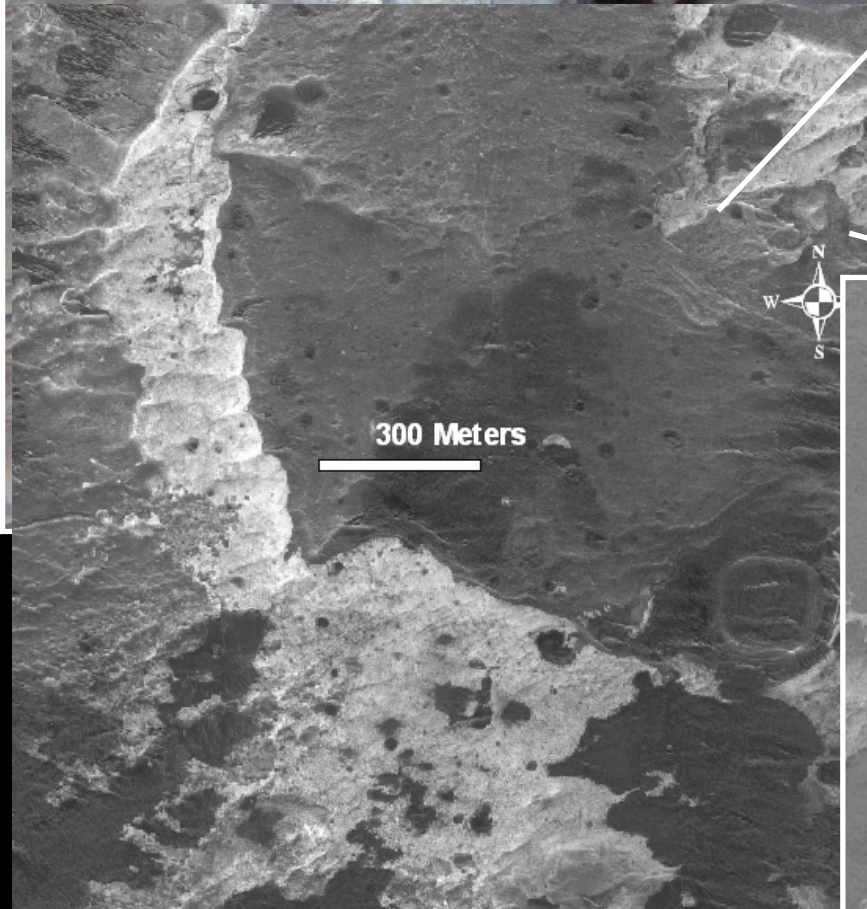
contacts

mineralogy

traverses



HiRISE image PSP\_100052\_1560



phyllosilicates detected by CRISM in  
layered light-toned rock (Milliken *et al.*, 2007)



fractured and layered light-toned unit  
context units

sinuous ridge (possible inverted channel)



# Traverse Distance Comparisons (from ellipse center)

	A	B	C
	Direct to Delta	Southern Route	Northern Route
Discontinuous Light-Toned Unit	0 km	0 km	0 km
Brecciated Ridge-Forming Unit	~ 1.0 km	~ 1.0 km	~ 1.0 km
Fractured Light-Toned Unit	~ 5.6 km	~ 5.6 km	~ 4.4 km
Layered Light-Toned Unit	~ 13.8 km	~ 13.6 km	~ 5.6 km
Sinuuous Ridges	~ 13.8 km	~ 11.2 km	~ 10.9 km
Linear Ridges	~ 15.4 km	~ 13.0 km	~ 21.6 km
W Delta Deposits	~ 13.8 km	~ 17.1 km	~ 21.6 km

context

units

contacts

mineralogy

traverses

# Conclusions:

- There's more to the Eberswalde story than The Delta:
  - the same sequence of light-toned rock units are associated with 6 other drainage systems within the crater
- This characteristic sequence of units is accessible within the ellipse:
  - discontinuous, light-toned unit
  - polygonally fractured, light-toned unit
  - layered, light-toned unit
- Context, context, context:
  - source to sink continuity
  - multiple drainage systems sample different source regions

Variety of other rock types within landing ellipse:

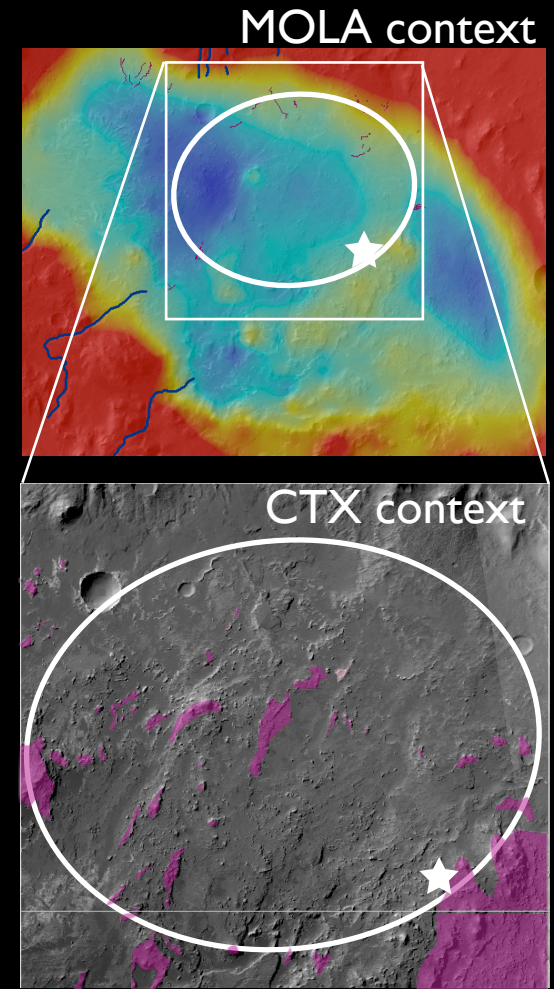
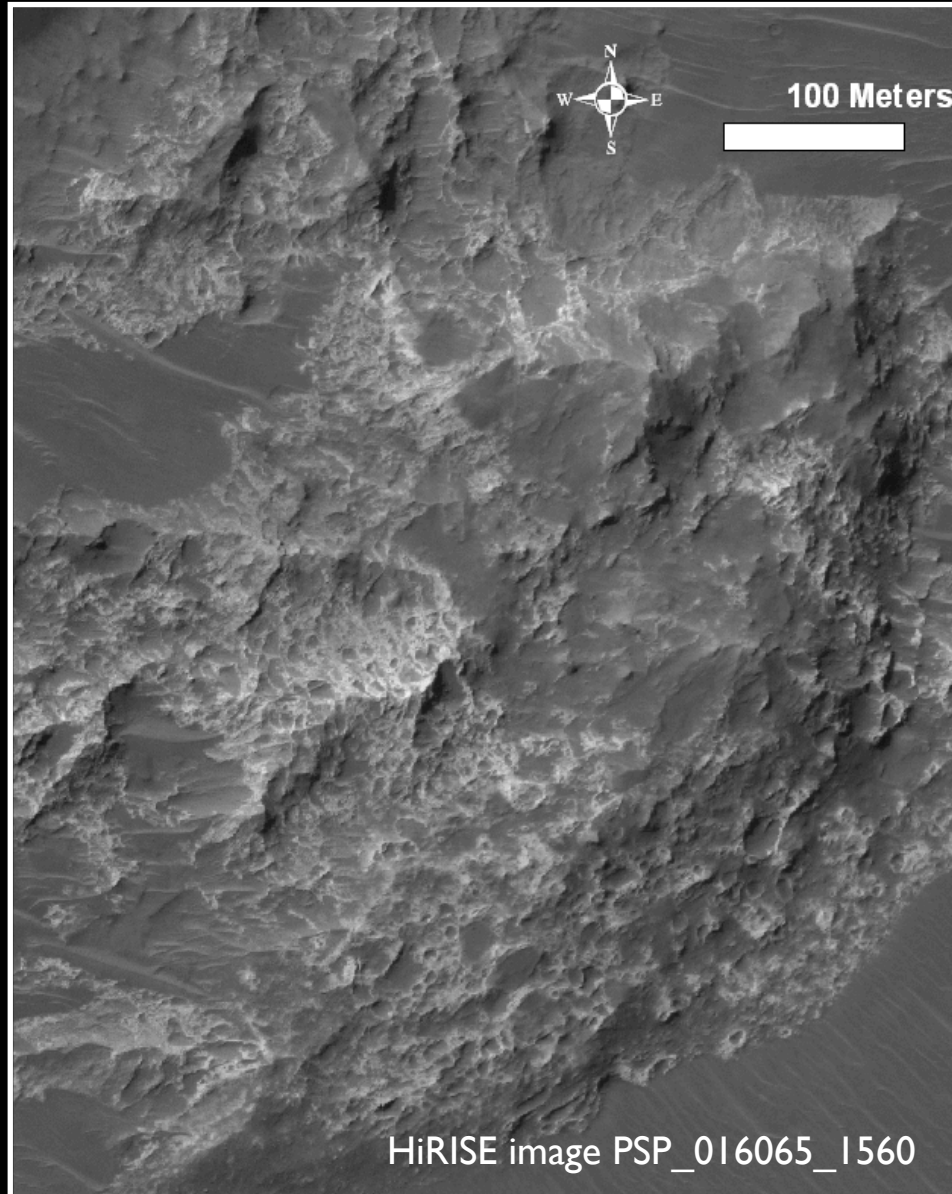
- megabreccia with clay mineral signatures
  - indurated dunes
  - inverted sinuous channels
- Lots of material has been removed:
    - sediments from a "Lake Eberswalde" may no longer exist throughout the basin, but could be preserved under inverted features (e.g. The Delta)



# Back-Up Slides

# 1. Brecciated Ridge-Forming Unit

## Morphology I:



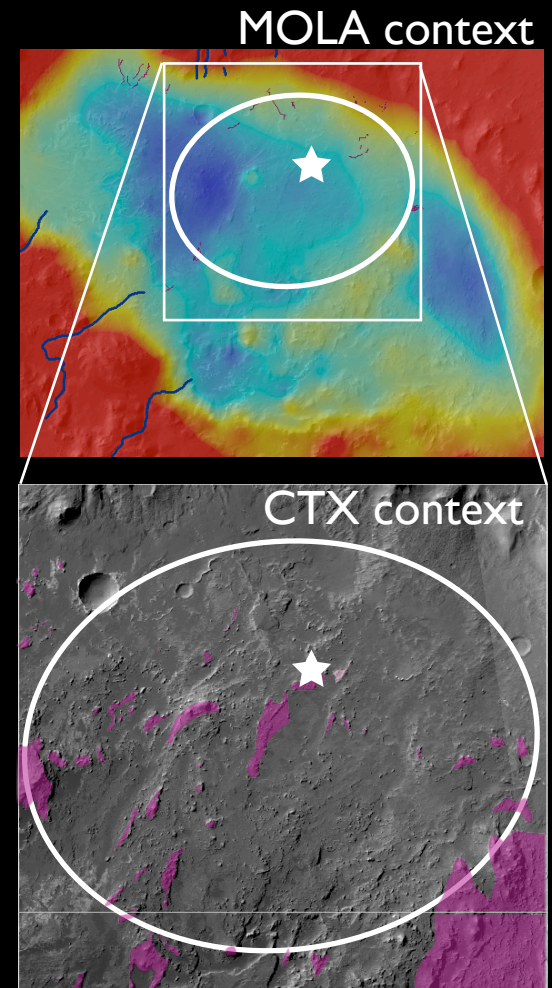
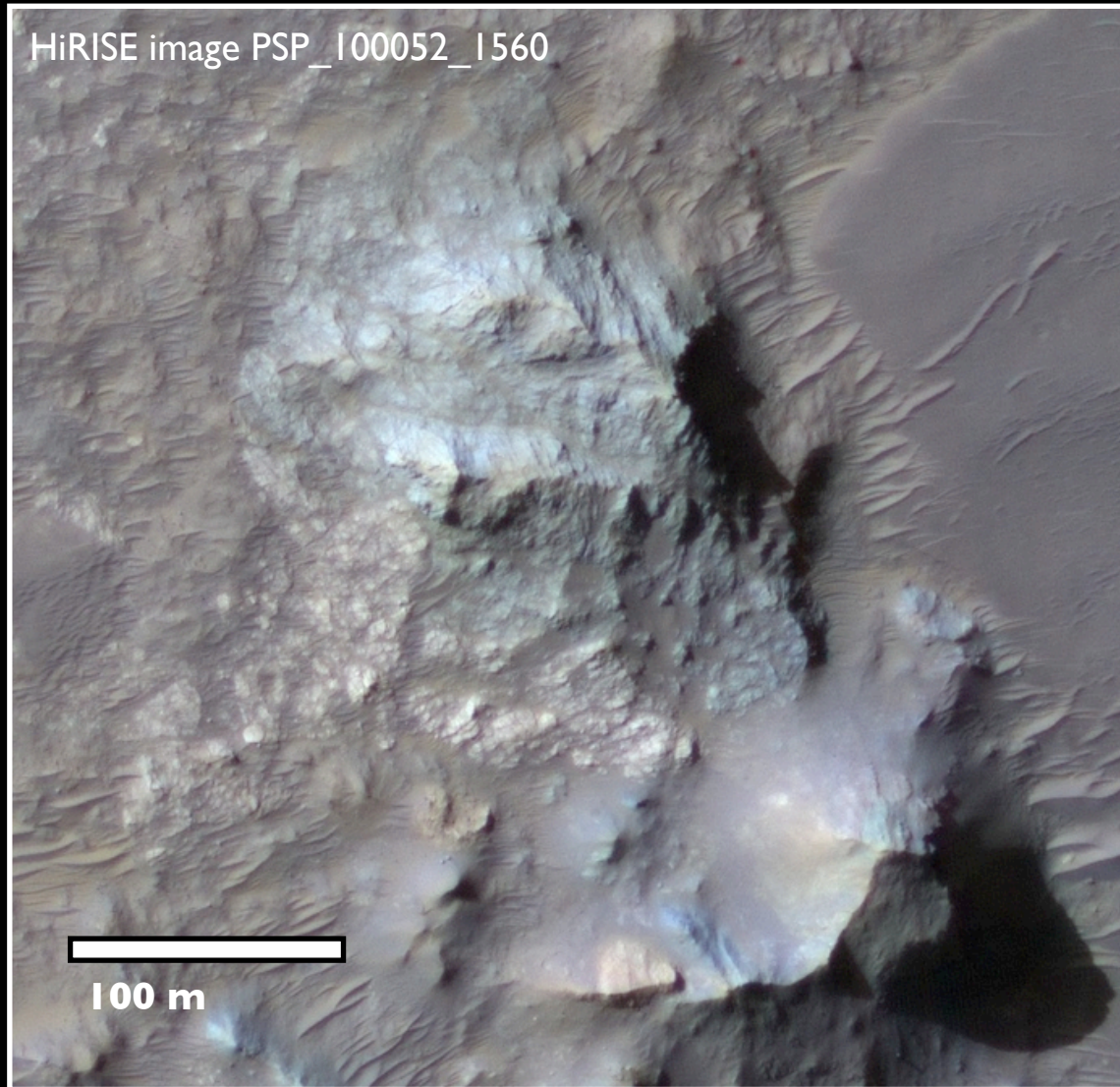
**OBSERVATION:** ~10m blocks  
encased in finer, light-toned matrix

**INTERPRETATION:** may be  
megabreccia from the Holden impact  
event (Scheiber *et al.*, 2008) or  
fractured bedrock

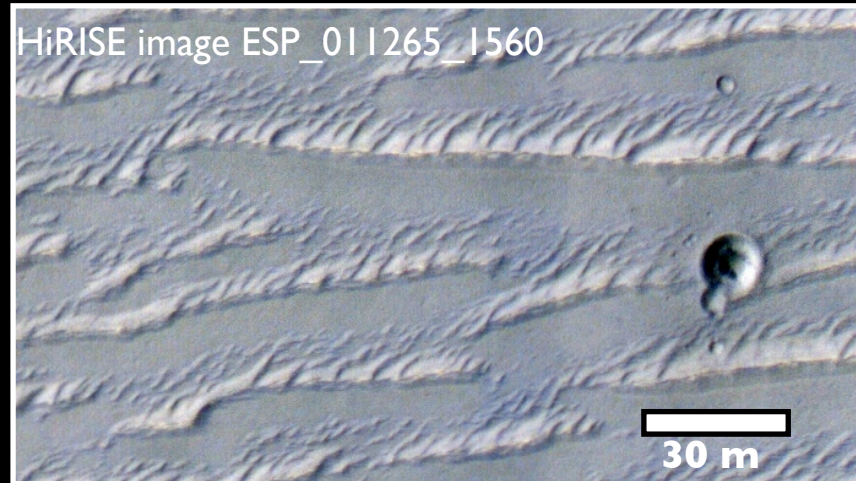


# 1. Brecciated Ridge-Forming Unit

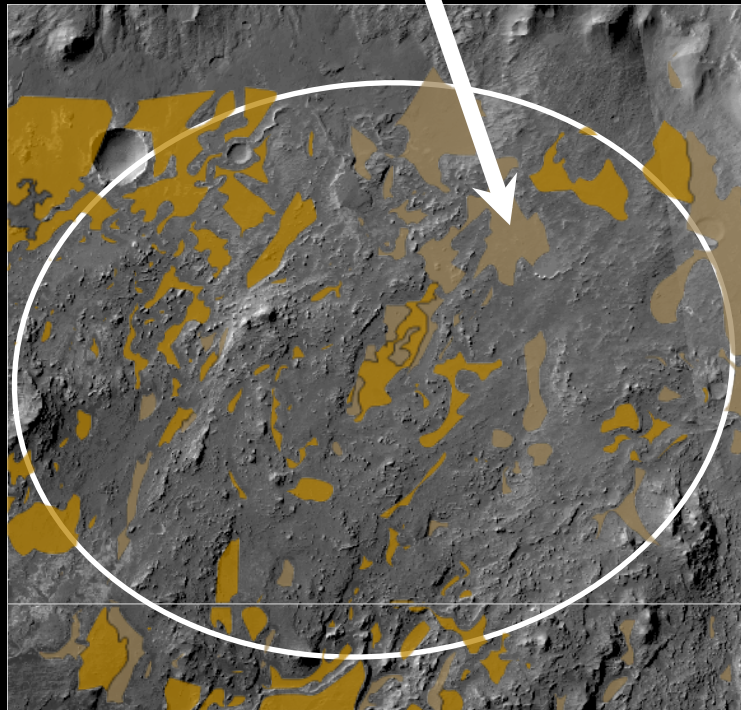
## Morphology II:



# Mantle and Bedforms



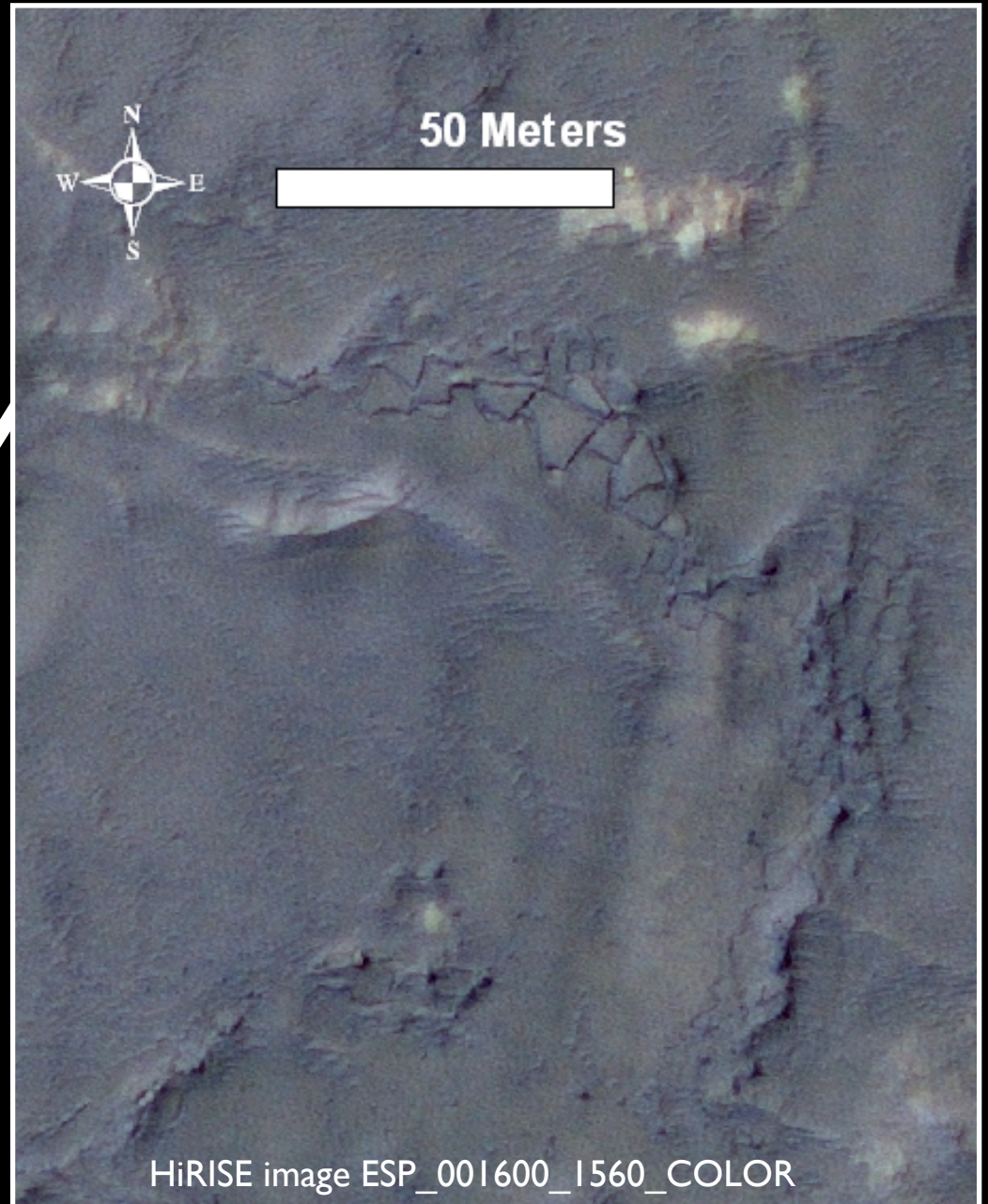
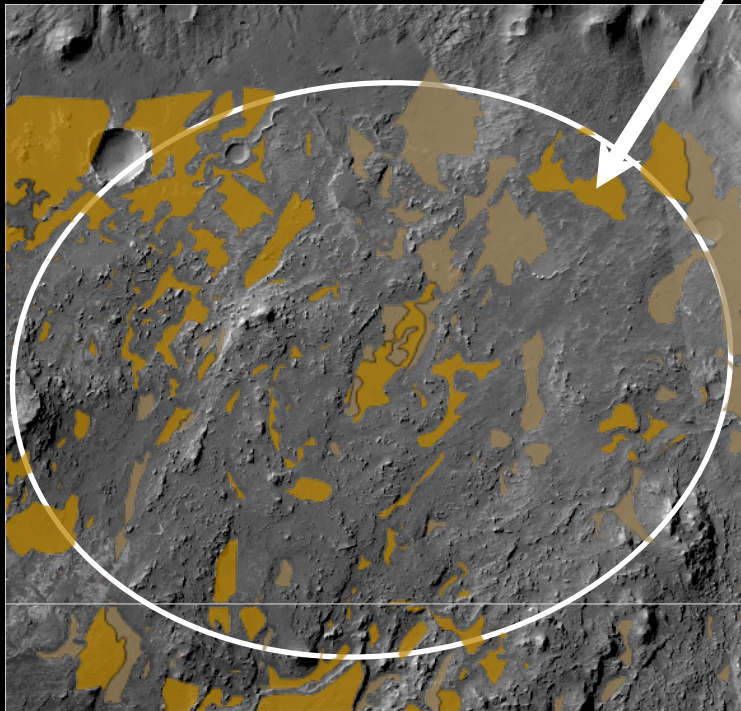
E-W orientation  
20-40 m spacing between dunes  
ripples indicate second wind direction  
crater retention implies dune induration



- Aeolian bedforms
- Mantling unit
- Inverted channels
- Layered light-toned unit
- Fractured light-toned unit
- Discontinuous light-toned unit
- Brecciated ridge-forming unit



# Mantle and Bedforms

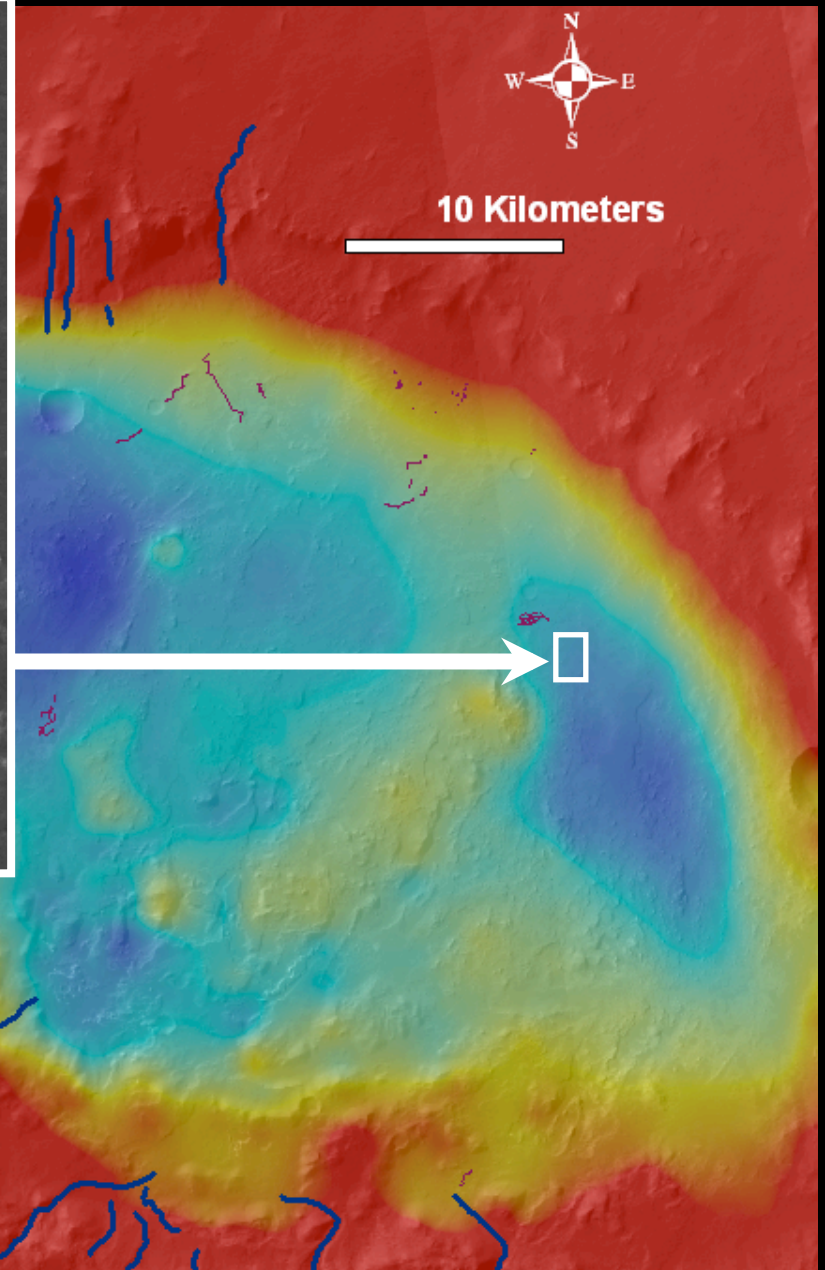


HiRISE image ESP\_013533\_1560\_RED

50 Meters



10 Kilometers



-1600 m

-1000 m

**Observations:**

eastern portion of crater covered by mantling and discontinuous light-toned unit, with isolated mesas of light-toned, polygonally fractured rock